Ethiopia's

Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC)

June 2022

Federal Democratic Republic of Ethiopia

Third National Communication (NC3) of the Federal Republic of Ethiopia

FORWARD

Given the already devastating impacts that climate change is already having on our people, environment, and economy, immediate global climate action is required to improve climate resilience and reduce greenhouse gas emissions. Despite the pressing economic challenges that confront us, Ethiopia has not relented on taking bold steps to deal with climate change, as reflected in its key policy and strategic frameworks, including the Climate Resilient Green Economy Strategy, the Ten-Year National Development Plan, Nationally Determined Contributions (NDCs), and the Long-Term Low Emission Development Strategy (LT-LEDs). Our Green Legacy Initiative, which has been championed by our Prime Minister over the last four years, has yielded concrete environmental and socio-economic benefits. Currently, there are various national initiatives on sustainable land management, renewable power generation, and food security that are geared towards building a climate-resilient economy in the country.

While these initiatives are already contributing to the attainment of the Sustainable Development Goals (SDGs), building resilience and achieving low carbon development. objectives, we need to do more if we are to achieve the goals outlined in the NDC and LT-LEDS.

To further warrant sustained focus on areas of climate change in the context of sustainable development, the country has also embarked on preparatory measures to ensure an effective transition towards the Enhanced Transparency Framework (ETF) of the Paris Agreement.

Ethiopia has prepared its Third National Communication (NC3) to the UNFCCC, in accordance with Article 4 and 12 of the Climate Convention, which call on all Parties to develop, periodically update, publish, and make available to the Conference of the Parties (COP) a National Communication including national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the COP. The Third National Communication follows submissions of the First and Second National Communications as well as the Revised Nationally Determined Contributions to the UNFCCC in 2001, 2015 and 2021, respectively.

As required for Non-Annex I parties, Ethiopia's NC3 encompasses information on National Circumstances, the National Greenhouse Gas Inventory, Mitigation Assessment, Vulnerability and Adaptation and Other Information relevant to the UNFCCC, which covers the Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forest and Other Land Use (AFOLU), and Waste sectors and information on mitigation actions and their effects; other relevant information and constraints, as well as capacity needs.

The NC3 national GHG inventory covers the period from 1994 to 2018. Ethiopia's emission contribution is negligible and accounts for only 0.53% of global GHG emissions. On the other hand, the climate vulnerability assessment indicates that agriculture, livestock, forest, water, biodiversity, health, infrastructure and tourism are the most severely affected sectors and require intensive climate smart adaptation interventions.

This Communication represents a further step forward in realizing Ethiopia’s goal of fostering growth through green technologies and pursuing sustainable development at all levels. Ethiopia remains fully committed to the long-term temperature goal set by the Convention and the Paris Agreement, and will continue to work with all national and international partners at all levels to pursue the decarbonized, resilient, and solidarity path she has already taken since the Convention's ratification.

In conclusion, I would like to emphasize that, as we take action to mitigate climate change at the national level, more concrete international efforts are required. I, therefore, call for international reforms to streamline access to climate finance in order to supplement national funding for climate-change-related initiatives.

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Minister

Ministry of Planning and Development

ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Center for International Agricultural Research
ACMAD	African Center for Meteorological Applications and Development
ADLI	Agricultural Development Led Industrialization
ADLI	Agricultural Development Led Industrialization
AFOLU	Agriculture, Forestry and Land Use
AGB	Above Ground Biomass
AGOA	African Growth and Opportunity Act
AGP	Agricultural Growth Programme
AGP	Agricultural Growth Program
AR4	Assessment Report (IPCC, 2007)
ATA	Agricultural Transformation Agency
BGB	Below Ground Biomass
CBD	Convention on Biological Diversity
CCIIDI	Chemical & Construction Inputs Industry Development Institute
CDM	Clean Development Mechanism
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CHPclim	Climate Hazards group Precipitation climatology
CIMMYT	International Maize and Wheat Improvement Center
CIS	Climate Information Services
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of Parties
CPAC	Climate Prediction and Application Center
CRGE	Climate Resilient Green Economy
CRGE	Climate Resilient Green Economy CSA Central Statistical Agency
CRU	Climatic Research Unit
CRU TS	Climatic Research Unit Time series
CSA	Central Statistical Agency
CSA	Climate–Smart Agriculture
DHS	Demographic and health survey

DOC	Degradable Organic Carbon
DOM	Dead Organic Matter
DW	Dead Wood
EF	Emission Factor
EFCCC	Environment, Forest and Climate Change Commission
EIAR	Ethiopian Institute of Agricultural Research
EIAR	Ethiopian Institute of Agricultural Research
ENSO	El Niño Southern Oscillation
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Authority
EPA	Environmental Protection Authority
EPACC	Ethiopian Program of Adaptation to Climate Change
EPACC	Ethiopian Program of Adaptation to Climate Change
EREDPC	Ethiopian Rural Energy Development and Promotion Center
ESIA	Environmental and Social Impact Assessment
ESTs	Environmentally Sound Technologies
ETB	Ethiopian Birr
ETCCDMI	Expert Team on Climate Change Detection Monitoring Indices
EtMS	Ethiopian Meteorological Society
EWCA	Ethiopian Wildlife ConservationAuthority
FACASI	Farm Mechanization & Conservation Agriculture for Sustainable Intensification
FAO	Food and Agricultural Organization
FEPA	Federal Environmental ProtectionAuthority
FOD	First Order Decay
GCF	Green Climate Fund
GDP	Gross Domestic Product
GER	Gross Enrollment Ratio
GERICS	Climate Service Center Germany
GFCS	Global Framework for Climate Services
GHG	Greenhouse Gas
GIS	Geographical Information System
GNI	Gross National Income
GoE	Government of Ethiopia

GTP	Growth and TransformationPlan
GTP II	Growth and Development Plan II
GTPI	Growth and TransformationalPolicy
GTZ	Gesellschaft fur TechnischeZusammenarbeit
GWh	Giga Watt hour
GWP	Global Warming Potential
HoF	House of Federation
HPR	House of People's Representatives
IAS	Invasive alien species
ICTP	International Center for Theoretical Physics
IGAD	Intergovernmental Authority on Development
ILRI	International Livestock Research Institute
INDC	Intended Nationally DeterminedContributions
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Uses
IRI	International Research Institute
ISWM	Integrated solid wastemanagement
ITCZ	Intertropical Convergence Zone
IWMI	International Water ManagementInstitute
LDCs	Least Developed Countries
LED	Light Emitting Diode
LRT	Light Rail Train
LSD	Lumpy Skin Disease
LULUCF	Land Use, Land-Use Change and Forestry
MCF	Methane Correction Factor
MMS	Manure Management System
MoA	Ministry of Agriculture
MoFED	Ministry of Finance and Economic Development
MOH	Ministry of Health
MoI	Ministry of Industry
MoT	Ministry of Transport
MoUDC	Ministry of Urban Development and Construction
MoWR	Ministry of Water Resources

MRV	Monitoring Reporting andVerification
MSW	Municipal Solid Waste
MTEIRDC	Manufacturing Technology & Engineering Industry - Research & Development Center
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Program of Action
NAP–ETH	Ethiopia's National Adaptation Plan
NARS	National Agricultural Research System
NCC	Norwegian Climate Centre
NDC	Nationally Determined Commitment
NFCS	National Framework for Climate Services
NFI	National Forest Inventory
NFPAs	National Forest Priority Areas
NGOs	Non-Governmental Organizations
NMA	National Meteorological Agency
NMI	National Metrological Institute
NRM	National Resource Management
OA	Quality Assurance
ODS	Ozone Depleting Substances
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
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PSNP	Productive Safety Net Programme
QC	Quality Control
RAC	Refrigeration and Air Conditioning
SBP	Satellite-based precipitation
SDGs	Sustainable Development Goals
SDPRP	Sustainable Development and Poverty Reduction Program
SLM	Sustainable Land Management
SLMP	Sustainable Land Management Programme
SNV	Netherland Development Organization
SOC	Soil Organic Carbon
SSA	Sub-Sharan Africa

SSGI	Space Science and Geospatial Institute
SWC	Soil & WaterConservation
TVET	Technical and Vocational Education &Training
UNCC	United Nations Climate Change
UNDP	United Nation Development Program
UNEP	United Nation EnvironmentalProgram
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNWTO	World Tourism Organization
USAID	United States Agency for International Development
USAID	United States Agency for International Development
WFP	World Food Program
WHO	World Health Organization
WLRC	Water and Land Resource Center
WMO	World Meteorological Organization
WTTC	World Travel and Tourism Council

LIST OF STANDARD

1 mega joule (MJ	10^6 joules
1 gigajoule (GJ)	10^9 Joules
1 terajoule (TJ)	1012 joules
1 pet joule (PJ)	1015 joules
1 exajoule (EJ)	1018 joules
1 toe	41.868 *109 Joules
1 ton	1,000 kilograms
1 cubic metre	1,000 liters
1 gallon	3.785 liters
1 ton	1 megagram
1 kiloton	1 gigagram
1 megaton	1 teragram
1 gigaton	1 petagram
1 kilogram	2.2046 lbs
1 hectare	10,000 m
1 calorie	4.1868 joules
1 atmosphere	01.325 kPa
Bt	billion tons
cc	cubic centimeter
Dm	dry matter
g	gram
Gg	gigagrams
GW	gigawatts
GWh	gigawatt-hours
Ha	hectare
J	joule
L	liter
l/s	liters per second

mm	millimeters
m3	cubic metre
mamsl	meters above mean sea level
mbmsl	meters below mean sea level
m/s	meters per second
Mt	million tons
MW	megawatt
Mwe	megawatt electrical
MWh	megawatt-hour
OC	degree Celsius
t	ton
tC	tons of carbon
Wh/m²	watt hours per square meter

GLOBAL WARMING POTENTIALS (GWP)

Gas	CO_2 Equivalent
CO_2	1
CH_4	25
N_2O	298
HFC-134a	1430
HFC-243fa	1030

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EXECUTIVE SUMMARY

ES 1. NATIONAL CIRCUMSTANCES

1.1 Geography, History and Governance

Ethiopia has an area of about 1.13million Km^2 and it is the 8th largest in Africa and 25th in the World. It has a complex topography of high rising mountains, plateaus, valleys and gorges extending from highlands to lowlands. The central plateaus are densely settled and cultivated areas with altitudes extending from 1300 m.a.s.l to more than 3000 m.a.s.l, some afro-alpine mountains rising above 4500 m.a.s.l. Over 70% of the country is arid and semi-arid, with high temperature and low rainfall. Ethiopia is one of the oldest nations in the world and cherishes 3000 years of ancient civilizations. Ethiopia has maintained its freedom by defeating colonial aggression in 1889. Coffee and other cereal crops have been contributed to the World from Ethiopia. Ethiopia is the origin of mankind, Homo sapiens and the only country in Africa that has its own scripts/alphabets. The governance is a federal system that provides autonomy to regional states. There are 11 autonomous regional states and two chartered city administrations.

1.2 Climate, Agro-Ecology and Land Use

Ethiopia has several distinctly identifiable climate regions in the landscape. The Inter- tropical Convergence Zone (ITCZ) determines the seasonal distribution of rainfall. There are two rainfall seasons, namely, Belg and Kiremt. The main rainy season (Kiremt) accounts for 50-80% of the total annual rainfall. Climate change is a serious challenge to Ethiopia. The country is one of the most vulnerable and the least ready to overcome the impacts of climate shocks. From past records, the mean annual temperature has increased by a magnitude of 0.2 °C to 0.28 °C per decade in the past six decades. The projections for the future clearly show that temperature will rise with in a range of 0.5°C to 2°C by the 2050s relative to the current state. Based on the temperature, dominant crop types and the length of the growing periods, the country has over 30 agro-ecological and sub-agro-ecological zones. The dominant land use types include agricultural land (cultivated land), forest land/vegetation, grazing land/rangeland, wetlands and settlements. In the past decades, the trend the land use change has been from natural to agricultural landuse.

1.3 Demography and Social Profile

Ethiopia is the second populous country in Africa next to Nigeria. The population has increased from time to time. The total population which was 53.5 million in the 1990s has reached 110 million in 2018 and is projected to reach 136 million by 2037. Ethiopia is the least urbanized country compared to most African countries, with only 22.8% of the population living in urban centres, which is expected to rise to 31.1% by 2037. However, Ethiopia has the fastest annual rate of urbanization with 4.5%, which is higher than the Sub-Saharan Africa average.

Ethiopia has made substantial improvements across the education sector since the early 1990s. Primary enrolment rates have improved markedly, with net primary enrolment climbing from nearly 40% in 2000 to 85% in 2014 and 109.5% in 2017/2018. Total educational attainment (for the population aged

15 and older) is nearly 20% lower than in the rest of low-income African countries. In 2016, the average years of education for adults (aged 15+) was 3.8 years, 4.4 years for males and 3.2 years for females. This is lower than the average attainment for low-income African countries, which stood at around 4.5 years in 2016. Concerning health, over the last two decades, the GoE has established 16,440 health posts and 3,547 health centers and has built 311 hospitals. As a result, Ethiopia has increased life expectancy by 40% and reduced infant mortality by 60% in the past decades. Access to improved water and sanitation is rising rapidly. According to the 2016 DHS, about 65% of the households in Ethiopia have access to improved sources of drinking water. Access to improved sanitation increased by 19% from 2000 to 2015. Despite that progress, Ethiopia ranks 32nd among 54 African countries and 162nd in the world in terms of the percentage of its population with access to improved sanitation facilities.

1.4 Economic profile and infrastructure

Ethiopia has registered notable economic growth and considerable poverty reduction in the past two decades. Real GDP has increased from $ 8.24 billion in 2000 to $29. 93 billion in 2010 and $84.3 billion in 2018. GDP growth between 2001-2010 averaged 8.74 %, it has averaged 9.73% in the periods between 2011-2018. In terms of sectoral contribution, the service sector (40%) has received the most considerable proportion of GDP in the economy in the consecutive years, followed by agriculture (37%), and industry (23%). Regarding sub-sectors, crop production accounts for 65% of the agricultural sector, while animal farming & hunting, and forestry each account for 8.6%. While crop production increased by 5.7%, animal farming & hunting and forestry increased by 5.8% and 3.9%, respectively. Manufacturing is the industry sector that contributed to 23.4% of the total industrial production. The construction industry registered a 6.6% expansion with a 72.2% share in industrial output, with roads, railways, dams, and residential house construction playing a significant role. The mining and quarrying sector's expansion trend was maintained in, with a 115.4% increase Ethiopia’s strong economic growth has helped to achieve social gains across sectors and halved poverty over the past decade. The sharp decline in poverty is attributed to economic growth and partly to the implementation of social protection programmes, such as the Productive Safety Net Programme (PSNP) as well as urban food distribution and subsidies. In 2016, Ethiopia’s government expenditure amounted to 16% of GDP, while revenues accounted for close to 22% of GDP, both lower than the rates seen in other low-income African countries.

Agriculture is the largest generator of export earnings in the economy. Although the country has large cultivable land, the total cultivated land for crop production is only 12.9 million hectares. About 81.5% of this land is used for the production of cereals, 12.2 % for pulses and 6.4% for oil seeds. The total grain production reached 335.2 million quintals, of which cereal production accounted for 88.5%, while pulses and oilseeds comprised 11.5%. Crop production contributes 32.7% of the agricultural GDP. Ethiopia has the largest livestock population in Africa. Like cropping, livestock rearing is mainly based on either mixed farming or pastoralism. Ethiopia’s livestock population is the largest in Africa, with 60 million cattle, 31.3 million sheep, 32.7 million goats, 1.4 million camels and 56.9 million poultry.

Industrial development in Ethiopia is extremely low. Ethiopia’s manufacturing sector is small, even by African standards. From the mid-2000s, Ethiopia’s ADLI strategy was supplemented with investment in various light manufacturing sectors, with mixed effects. In some sectors (i.e., cut flowers), the strategy was successful, and in other areas (i.e., agribusiness and leather processing), it was less successful. Manufacturing growth barely kept up with Ethiopia’s overall economic growth rate, and the GDP share of the manufacturing remained around 4.5% over the past decade. The business environment for Small and Medium Sized Enterprises (SMEs) and other private firms is also hindered significantly by low access to finance, unreliable supply of electricity, and lack of access to land.

The export structure of Ethiopia has been characterized by greater concentration of few exports such as coffee, oil seeds, pulses and Khat. Coffee dominates the total merchandise export item of the country and accounts for 29.5% of visible export earnings. Meanwhile, service export was largely driven by the growth of Ethiopian Airlines, the country's flagship airline carrier. Ethiopia's public investment strategy resulted in high demand for significant quantities of capital and construction equipment, leading to a persistent trade deficit of between 16% and 22% the past decade. The trade deficit in 2018 was at about 18% of the GDP, which is a bit higher than the African low-income average and significantly higher than regional counterparts. Transport service plays a key role in the implementation of national development plans. Over the last two decades, both the road network and density have increased. During 2004/05 the road network was 37,018 km while the total road network increased rapidly and reached 126,773km during 2017/18. Likewise, the road density/1000 persons, which was 0.5 in 2004/5 has increased to 1.3 in 2018/19. The road density/1000 square kilometers, which was 33.7 in 2004/5, has also improved in a way to 100.4 in 2015/16 and further to 115.2 in 2018/19. Air transport is an important part of the country's transport network. Serving part of the transport network, it takes second rank after road transport in carrying passengers and cargo in the country. Ethiopia is a regional leader in air transportation. Ethiopia Airlines, one of Africa's three top international carriers, has an extensive network across the continent and a safety record up to international standards.

The Ethiopian government has made huge investments in the telecom sector, focusing on improving quality of service, expansion of service coverage and enhancing institutional capacity. This policy measure has enhanced the capacity of Ethio-Telecom in terms of customer acquisition, customer satisfaction and provision of quality services to customers. Owing to this, the total number of mobile subscribers has reached 58.08 million in 2016/17 showing a 70.28 % increase in a decade. Tele density has increased from 21.4% in 2011/12 to 62.6% in 2016/17 but declined to 40.8% in 2017/18 due to the elimination of inactive mobile services. Ethiopia is endowed with unique landscape, paleontological, archaeological, historical and living cultural tourism attractions. Based on these attractions, there are diverse types of tourism in the country. Tourism is becoming an important sector contributing much to the social, cultural, and economic development aspects of the country. Ethiopia's renewable energy generation potential is untapped. The country has the potential of generating up to 45,000 MW from hydropower, 10,000 MW from wind, 5000 MW from geothermal and an average of 5.26 kWh per square meter per day from solar energy. Except for the biomass fuel, most of the presented energy source is either untapped or not fully developed. In its bid to become a major power exporter and green economy in East Africa, the country is building several geothermal power plants and the GERD.

1.5 Natural Resources, biodiversity and ecosystem services

The surface geology of Ethiopia is characterized by different formations along the rift valley and the outcropping highlands. According to the 1998 FAO soil classification, there are about 18 soil groups in Ethiopia. However, estimates show that about 80 % of the country is covered by nine major soil types. Some of these soil types and their percentage area coverage are Cambisols (21%), Regosols (20%), Nitosols (16%), Yermosols (13%), Xerosols (11%), Vertisols (5%), and Lithosols (7%), together accounting for 93% of the area covered by soil. Ethiopia has abundant water resources, but they are subject to high hydrological variability. Besides, studies indicate that the country has an annual surface run-off of close to 122 billion m^3 of water excluding ground water. The hydrology of Ethiopia forms a foothold for the water resources in the Horn of Africa, including Sudan and Egypt. Ethiopia has about 30 Lakes distributed all over the country, but more concentrated in the rift valley. Except for some lakes, which are deep and > 150 m, such as Lakes Shala (266 m), Babogaya (65 m), and some crater Lakes (Zengena Kibeb in Awi zone) and Lake Wonchi, most of the other lakes are shallow (about 20 – 50 m). Ethiopia is endowed with a variety of vegetation types encompassing the grasslands to the high mountain forest vegetation types distributed across the landscapes (from Dallol depression of 126 mbsl to the tip of the Ras Dashen Mountain at 4620 masl). As a result, there are twelve major vegetation types identified in the country. Ethiopia is one of the mega-diverse countries in the world and a large part of the country covers a large proportion of the two major biodiversity hotspots among the 34 in the world. These are the Eastern Afromontane and the Horn of Africa hotspots. Ethiopia is also the center of diversity and origin of several cultivated crops including Coffee arabica. There are an estimated number of over 6000 species of higher plants and 10% of which are endemic. Ethiopia has five distinct types of Ecosystems. These are Mountain ecosystems, Forest and woodland ecosystems, Aquatic and wetlands ecosystems, Rangeland ecosystems and Agro-ecosystem.

1.6 Waste Management

Although Ethiopia has ratified most conventions related to waste management and handling (e.g. Basel, Stockholm, and Rotterdam conventions), and passed sound policies and legislations to manage waste, there is a clear lack of sound management of environmentally hazardous chemicals and wastes. Existing policies and laws on waste management are not strictly implemented. Waste generation is directly linked to population growth and urbanization. As the total population and the number of urban dwellers has been increasing annually, the waste generation has increased from 9,700 ton/day in 2015 to 12,200 ton/day in 2020. By 2030, the waste generation rate at national level will be doubled from that of 2015, i.e. 24,400 ton/day.

1.7 Key development Challenges

Ethiopia has seen great improvements in several sectors of its economy (especially in the areas of infrastructure) these past couple of years owing in part to the great Chinese investment and also to the intense government projects aimed at achieving its SDGs of attaining middle income status by 2025. Despite progress in economic growth, sustainability and equitable share of the fruits of economic growth are constrained by many challenges. Still, about 24 % of the population remain poor and the poorest in Ethiopia have become even poorer in the sense that the high food prices that improves income for many farmers, also makes buying food more challenging for the poorest especially those in the rural areas. Although more farmers are making good incomes from their farm produce, many people in Ethiopia today are unable to afford basic necessities like food due to the high prices.

Frequent severe weather events alongside long-term impacts of climate change undermine agriculture and pastoral livelihoods as well as food security. The incidence of conflict has increased from time to time leading to substantial impacts on lives, livelihoods, and infrastructure. Ethiopia has experienced the worst locust invasion and its effects contribute to threatening the food security and livelihoods of millions of Ethiopians. Ethiopia has a growing private sector, whose growth and job-creation abilities have been hindered by constraints in the business climate and competitiveness. The country's growing workforce (at 2 million per year) puts pressure on absorption capacity of the labour market, necessitates improving current jobs, while creating sufficient new jobs. A tourism rebound and liberalization of the telecoms sector are expected to boost the growth outlook. Key downside risks to the growth outlook include the civil conflict and debt vulnerabilities. Higher global food and oil prices are expected to increase inflation in the years to come.

ES 2. National GHG inventory

2.1 Summary of the national emission and removal

Emissions from the economic sectors have grown between the base year of 1994 and the most recent inventory year of 2018. These rising emissions were a result of the nation's two-digit economic expansion. Total national emissions in 1994 were 108,333 Gg of CO2e; in 2018, they were 350,843.9 Gg of CO2e, an increase of around 240%. The AFOLU sector is responsible for a large amount of these emissions, followed by energy (7%). The waste sector and IPPU contribute 1.26%, and 1.01%, respectively. From 60,774.2 Gg CO2e in 1994 to 108,422 Gg CO2e in 2018, the removal has increased by 79%. Interventions on the land subsector by the government such as afforestation, reforestation, and forest restoration have been responsible for the removal of GHG.

2.2 Source and sink category estimates and trends

The emission t rend of the AFOLU sector shows an increase in net emission from 19, 586.06 Gg of CO_2e in 1994 to 226,157.6 Gg of CO_2e. The majority of the overall emission came from the land as CO_2, with enteric fermentation CH_4 emission from the livestock subcategory coming in second. The burning of liquid and solid fuel takes up the largest share of the energy sector's GHG emissions. The total combined CO_2 emissions from the burning of liquid and solid fuels in the energy sector gradually increased from 1632.9605 Gg CO_2 eq in 1994 to 12516.2188 Gg CO_2 eq in 2018. The CO_2 emission from the transport sector (48%) contributes nearly half of the total CO_2 emission in the energy sector. The manufacturing and construction industries (29%) played the second largest role which is followed by the energy industries (14%). The other sectors contribute the least (7%) to overall CO_2 emissions in 2018. Total aggregated emissions for the IPPU sector ranged between 200.102 Gg CO_2-eq and 3747.846 Gg CO_2-eq during the period 1994 to 2018 with an annual averageof 1427.785 GgCO_2-eq.Thecement industry is responsible for 97% of the aggregated emissions followed by lime production with 3 %. There is a growing rate of waste generation, especially in the urban areas due to population increase, urbanization, and industrial development and thus an increase in GHG emissions from the waste sector. From 1994 to 2018 the GHG generated from waste generated (in cities) more than doubled increasing from 1565.59 Gg CO_2-eq in 1994 to 4656.82 Gg CO_2-eq in 2018. Of total gasses emitted (374,878.3 Gg), CO_2 contributes 98.36 percent, CH_4 (1.63 percent), and N_2O (0.01 percent).

2.3 Energy

The energy sector is a pillar for economic development of a country by providing a reliable supply of energy to various economic and social sectors. Ethiopia has enormous renewable energy potential and it is undertaking great effort towards the development of renewable energy technologies and green legacy. From the hydropower alone, Ethiopia has untapped potential up to 45,000 MW, of which only five percent has been exploited. Ethiopia's annual average daily irradiance for solar energy is estimated to be kWh/m2/day. Moreover, Ethiopia has a potential of 10,000 MW and 5,000 MW from wind and geothermal energy sources, respectively (Tiruye, 2021, Adams, 2018, Mengitu 2017 and Guangul, 2021). However, despite all these huge amounts of renewable energy sources, only 5% of its full hydroper is exploited and others are fully unexploited or not well developed to date. The traditional biomass fuels, which made up around 87% of the country's total primary energy use, include charcoal, fuel wood, dung cakes, and agricultural waste (Tiruye, 2021). Ethiopia intends to generate foreign exchange through utilizing all of its potential for producing electricity, mostly from hydropower plants. The enormous amount of electricity generation hydropower like the Ethiopian Renaissance Dam will also contribute to the region's economic integrity.

Ethiopia raised its use of biomass fuels from 2.8 million TJ in 1994 to 3.3 million TJ in 2004. However, the biomass fuel usage fell sharply to 1.2 million TJ in 2005 and stayed nearly steady up to 2018. This is mostly due to a policy intervention such as a decrease in biomass fuel usage for lighting and cooking in the country as a result of new electric power supply added to the national grid, increased distribution of improved cook stoves, use of off-grid systems from small-scale solar energy and the growth of condominium housing which are connected to the national grid in the major cities of Ethiopia.

The combustion of fossil-based liquid fuels such as gasoline and diesel used in the transportation sector are the largest source of direct CO_2 emission in Ethiopia which is followed by manufacturing industries and construction subsectors. The total combined CO_2 emissions from burning of liquid and solid fuels in the energy sector gradually increased from 1632.9605 Gg CO_2 eq in 1994 to 12516.2188 Gg CO_2 eq in 2018. The CO_2 emission from the transport sector (48%) contributes nearly half of the total CO_2 emission in the energy sector. The manufacturing and construction industries (29%) played the second largest role which is followed by the energy industries (14%). The other sectors contribute the least (9%) to overall CO_2 emissions from the energy sector in 2018.

2.4 Industrial Processes and Product Use (IPPU)

The IPPU sector comprises GHG emitted as by-products during industrial processes for the manufacture of new products. The categories covered are 2.A-Mineral Industry Category (Cement, Lime, Glass and Ceramic Production), 2.B- Chemical Industry Category (Soda Ash Production), 2.C - Metal Industry (Iron and Steel Production), 2.D - Non-Energy Products from Fuels and Solvent Use (Lubricant, Paraffin Wax Use, Asphalt and Bitumen), and 2.F - Product Uses as Substitutes for Ozone Depleting Substances (Refrigeration and Air Conditioning and Foam Blowing Agent).

Total aggregated emissions for the IPPU sector ranged between 200.102 Gg CO_2 eq and 3747.846 Gg CO_2 eq during the period 1994 to 2018 with an annual average of 1427.785 Gg CO_2 eq. Ethiopia's National GHG Inventory time series in terms of IPPU sector shows a steady increase in trend, with significant increments starting from 2012 CO_2 emissions increased by about 43% from 1570.92 Gg in the year 2011 to 2793.65 Gg in 2012. Based on the recalculated value, in 2013 the cement industry is responsible for 97% of the aggregated emissions followed by the lime production with three percent. The contribution of the rest of the industrial processes and product uses was almost 0%. Similarly, in 2018, the cement and lime production contributed the highest share of CO_2 emission, which were 85% and 15%, respectively. Iron and steel production and Cement production were indicated in the SNC with 48% and 51% contribution, respectively. However, from recalculation in the period of 1993 to 1994, and emission estimationinthe periodof2014to2018,cementhasthelionshareinthenationalGHGemissionfromIPPU sector.

2.5 Agriculture, Forestry, And Other Land Use (AFOLU)

A significant portion of Ethiopia's overall GHG emissions come from the AFOLU sector activities. The totalamountofCO_2eemissionsin2018was334,579.8Gg.Ontheremoval side,theAFOLUsectoriscrucial, asitremoved108,422GgofCO_2ein2018.In2018,this sector'snetGHGemissionswere226,157GgofCO_2e. Themajorityoftheoverallemission came from the land as CO_2, with enteric fermentation CH_4 emission from the livestock subcategory coming in second. According to gas emission data, CO_2 has a total value of 231,830.5 Gg of CO_2 eq, CH_4 has a total value of 96,144.01 Gg of CO_2e, and N_2O has a total value of 96,144.01 GgofCO_2eq.Theemissiontrendofthissectorshowsanincrease ofnetemissionfrom19,586.06 GgofCO_2eqin1994to226,157.6Gg of CO_2eq.

2.6 Waste

Ethiopia is one of the fastest growing countries in sub-Saharan Africa and the second populous country in Africa. There is also a rapid rate of industrialization coupled with change of lifestyle of the people which leads to generating huge volumes of solid waste and wastewater from domestic and industrial sources. The rate of MSW in Ethiopia is estimated to be 6 million tons per year in 2015 and is predicted to increase to 10 million tons per year by 2030 and 18 million tons per year by 2050. In Ethiopia waste is generated from a number of sources; households, institutions, industries, commercial centers. The household sector is estimated to be the major waste generator accounting for between 53–76% of the total weight of waste generated in Ethiopia. Over the years the country has registered growing trends of waste generation per capita in line with the country's economic growth and increased urbanization. Both increased volumes and complexity of waste have occurred with current estimates at 0.31 kg/capita/day. In Addis Ababa City, waste generation increased from 0.25 to 0.45 kg/capita/day from 1995 to 2017 with annual waste quantity increased significantly by 80%. Also, projections indicate that annual waste of Addis Ababa City would be approximately 3,569 ton/day in 2030 (Addis Ababa Solid Waste Management Agency, 2020). The national growth rate is mainly attributed to population growth, urbanization, per capita income, economic growth and the overall industrialization. The urban solid waste is mainly composed of vegetable/organic matter (67.4%), plastic (7.9%), and wastepaper (5.7%). Other materials include: metals (0.63%), and glass (1.15%) while other miscellaneous materials constitute17.2%. The major challenges for urban centers are waste collection, transportation, treatment, storage, and disposal, and as such a lot of indiscriminate waste disposal practices have become common among households.

There is also a growing rate of wastewater generation from both domestic sources and industries in the urban areas of the country. The sources for industrial wastes are textile and garment industries, tanning industries, beverage industries and industrial parks. There is a growing rate of waste generation especially in the urban areas due to population increase, urbanization and industrial development and thus an increase in GHG emissions from the waste sector. From 1994 to 2018 the GHG generated from waste generated (in cities) more than doubled increasing from 1565.59 Gg CO_2-eq in 1994 to 4656.82 Gg CO_2- eq in 2018. Methane emissions are dominant in the entire waste sector and mostly from the solid waste disposal subcategory. Wastewater treatment and discharge are the

main sources of emission contributing 93.6% of the total emission in 1994 and 87% in 2018 (Fig. ES-7). The contribution of emissions from solid waste increased from 3.8% in 1994 to 87% in 2018. The emission from the biological treatment of waste increased from 0.00% in 1994 to 100% in 2018, while the emission from burning of solid waste and incineration was the least contributor.

ES 3. GHG Mitigation assessment and policy measures

Although Ethiopia is not obliged, under the climate change convention, to reduce its GHG emissions. The government is seriously working towards reducing GHG emissions. Due to its green growth policy and low-carbon development pathways, the country is willing to reduce its GHG emissions despite its negligible (0.5%) contribution to world GHG emissions. Ethiopia contributed 350,843.9 GgCO2eq. to total world GHG emissions in 2018, removing 108.4 Gg CO2e, leaving a net emission of 260.4 Gg CO_2e, which is about 0.5% of total global emissions (49.7 Bt CO2) in the year 2018. The TNC GHG emission is higher when compared to SNC GHG emissions inventory (146,160.43 GgCO2eq.) attributed to economic development and change in activity data and methodology. Of the 350,843.9 Gg CO2e GHG emissions in 2018, was more than 90% come from the AFOLU, and followed by the energy sector. The majority of the overall emission came from the land as CO2, with enteric fermentation CH4 emission from the livestock subcategory coming in second. The total projected GHG emission was estimated to be 403.5 Gg CO2-eq in 2030 for the increasing trend in the business-as-usual scenarios.

Ethiopia has put in place several initiatives with the potential to contribute to climate change mitigation and assessment measures to reduce the emissions of GHGs and /or enhance their sinks. As indicated in CRGE, the country is committed to work on reducing vulnerability of Climate change impacts through strengthening holistic integration of climate change adaptations in development policies and strategies at the national as well as Regional and Woreda levels. The country's second National Communication to the UNFCC, identified several mitigation options in AFOLU, sector (agriculture, land use, land use change and forestry), the energy sector, IPPU and waste sector. Most of these measures have been implemented and are contributing not only to GHG mitigation, but also to the country's sustainable development objectives. The primary policies that have been created within the context of this approach are as follows:

I. The National Climate-Resilient Green Economy (CRGE), which was approved in 2011 to better outline and design implementation strategies for GHG reduction alternatives. CRGE serves as the main framework for GHG emission mitigation. The CRGE aims to promote green growth, low-carbon emission, and high economic growth and create a society that is climate resilient.

II. National Adaptation Plan (NAP) addresses climate change in the country's development policy framework including the CRGE strategy as well as sectoral climate resilience strategies regional and municipal adaptations plan. NAP implementation roadmap (2019) specified 40 adaptation interventions. Ethiopia isensuringthelegacyinitiativetosurpassitsgoalofplanting20billiontreesunder theGreenLegacyInitiativebythePrimeMinister,whichenhancescarbonsink.

National Determined Contributions (NDC 2021) forecasts for climate change mitigation contributions under three different GHG reduction scenarios: the unconditional, conditional, and business-as-usual (BAU) pathway. According to the SNC the 2030 absolute emission level under the unconditional approach will be347.3MtCO$_2$ewithareductionof68.8%(-277.7MtCO$_2$e)incombinedimpacts of unconditional and conditional pathways. Unfortunately, the TNC inventory reported **350,843.9 Gg** GHGemissionsin2018 andprojectedto403.5Mtin2030which requires effective implementation of policies and plans.

III. Additionally, sector-specific priority actions for mitigation and adaptation strategies were identified and prioritized in the amended NDC. As a result, it has already taken a number of steps to encourage mitigation based on local conditions. These include undertaking large-scale investments in the potential of hydro, solar, and wind energy as well as undertaking green legacy initiatives and afforestation projects.

Some of the proposed mitigation options in the energy sector include: shifting the energy system to grid-connected electricity generation that comes from renewable sources (solar, wind, and small hydropower), improving resource and energy efficiency in manufacturing processes and the use of efficient improved stoves at the household level. The country is also implementing an Intra-urban Electric Rail NAMA with the overall objective of replacing 50 per cent of the transport of cargo with electric rail under the CRGE strategy. The other options include the use of efficient vehicles (electric car), alternative fuels (bio-diesel), improve the share of blending ethanol-gasoline (gasohol), improving rural and urban transport infrastructure, promoting mass transportation and the use of non-motorized transport,suchascyclesandothertypesofintermediatetransport.

The primary IPPU sector mitigation options focus on emissions from cement production. These include (1) Addition of specific decarbonated or limestone-free components to the raw materials mix, before kilning, (2) Substituting a portion (up to 30 to 40 %) of the clinker with supplementary cementitious materials (SCM) without compromising cement strength. SCM include industrial byproducts such as fly ash, bottom ash from waste-to- energy plants, ground granulated blast furnace slag (GGBFS), natural (volcanic) pozzolans, calcinated clay (metakaolin), bagasse ash, etc. and (3) Using limestone calcined-clay cements (LC3). These can replace up to 50% clinker and reduce GHG emissions by 30%. The components of LC3 are clinker, calcined clay, limestone,and gypsum.

The mitigation options identified in the AFOLU sector are divided into three categories: livestock, land/forestry and agricultural crops sub-sectors. The mitigation options need to be considered in Livestock sub sector include: Rangeland and pastoral land management, improving livestock production system (feed/forage diversification; improved animal breeds), enhancing and intensification of animal mix (dairy, poultry, small ruminants, improved breeds), Drought-resistant animal breeding, Animal health care and reproductive improvement, Manure management and Livestock value-chain efficiency improvement (processing, marketing). The mitigation options needs to be considered in land/forestry includes: improve management of natural forests and woodlands, increase afforestation, reforestation, and sustainable forest management, strengthen community-based forestry, sustainable forest management and conservation, reduce demand for fuel wood, Low-emission climate smart agriculture and improving agricultural production techniques, improved livestock production, value chain and management, strengthen law enforcement activities to combat deforestation and forest degradation, and Clean Development Mechanisms (CDM). The mitigation options need to be considered in agriculture su-sector includes: Soil carbon storage and management, Nitrogen Management, Tillage and residue management, Agroforestry, Smart agricultural practices, Water management techniques, Climate-smart agriculture, improve drought-resistant crop varieties, Watershed management and rehabilitation and Ecosystem-based adaptation.

Waste sector mitigation options Include: implementing integrated solid waste management program (source reduction, reuse/recycling, composting, and waste to energy program), promote Sanitary landfill, improve fecal sludge management system, implement integrated wastewater treatment systems, enhance sewer line connection, and promote zero liquid discharge.

ES 4. Vulnerability, impacts and adaptation assessment

Ethiopia is most vulnerable to climate change and extremes mainly due to its location, dependency of climate change sensitive sectors and low adaptive capacity. Climate change and extremes such as drought, flood, and temperature extremes, delaying of rainfall onset, early rainfall cessation, and high rainfall intensity have been compromising the sectors' performance and causing poverty and food insecurity. Thus, land degradation, shortage of pasture, water scarcity and pollution, the prevalence of epidemic pests and disease, infestation of invasive species, resource-based conflict, and migration are some of the manifestations of the direct and indirect impact of climate change and extremes. Overall, the cumulative effects of climate change worsen poverty and food insecurity which in turn would further erode adaptive capacity.

Precipitation data analysis confirms that annual and seasonal rainfall distribution exhibited high spatial-temporal variability and uncertainty of precipitation. The erratic precipitation in amount and distribution is projected to continue in the future. In southern, southwestern, and southeastern Ethiopia small rainy season and main rainy season rainfall decreased from 15-20% between the 1970s and 2000s. The reduction of rainfall by 15% to 20% could remarkably undermine crop and livestock production due to scarcity of water and moisture stress. Precipitation index analysis results show that the country has been affected by recurrent drought and flood hazard events due to extended periods of dry and wet conditions in different seasons and various parts of the country. However, in Ethiopia drought and flood simultaneously partly due to its varied topographic feature and influence due to large scale atmospheric and oceanic circulation. The contributing atmospheric and oceanic circulation indices for the extreme precipitation, including Multivariate ENSO Index (MEI), Southern Oscillation Index (SOI), Northern Oscillation Index (NOI), North Atlantic Oscillation (NAO), Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation(PDO).

Mean seasonal minimum temperature has increased by 0.024 °C from and by 0.06 °C between 1901 to 2020 and 1990 to 2020 respectively. Likewise, the mean seasonal maximum temperature has increased by 0.017 °C and 0.043 °C from 1901 to 2020 and 1990 to 2020 respectively. The result shows that Ethiopia has experienced a rise in temperature. However, the rate of seasonal maximum temperature increased faster than minimum temperature in recent decades. The mean seasonal temperature is expectedtoincreasefrom0.071^{0}Cto1.5^{0}CundertheRCP2.6scenarioby2050.Similarly, the mean seasonal temperature is projected to increase from 0.095 0c to 2 0c by 2050 under the 8.5 scenarios.Thismeansseasonaltemperatureincrementwillbefasterinthe south and southeastern part of Ethiopia. In general, the rise of temperature and recurrent drought and flood across the country could create a favorable environment for secondary hazards. In Ethiopia the impact of climate change and extremes is more visible in the agriculture, water, forest, health, biodiversity, tourism, and infrastructure resources. Climate change is an existing truth that the government must create appropriate and efficientadaptationplanstotackleitseffectsoninfrastructure.Additionally,loweringthe dangers associated with climate change should involve all parties. Data is crucial for analysis and decision-making. However, Ethiopia has insufficient infrastructure data; as a result, database enhancement is crucial.

ES 5. Other information considered relevant to the achievement of the objective of the convention

5.1 Integrating climate change in planning process

Integrating climate change adaptation and mitigation strategies, policies and Ethiopia's National Adaptation Plan (NAP–ETH) into the national development plans along with monitoring their implementation is shouldered by the EFCCC now the federal EPA. To this end, to successfully integrate, operationalize, and implement the strategies, sector ministries have established environment and CGRE directorates that are directly accountable to the minister. Moreover, EFCCC has developed a guideline entitled "Integrating the Climate–Resilient Green Strategy in Sector Development Plans" along with the necessary capacity building training helpful to integrate climate change adaptation and mitigation activities in sector annual and medium-term planning.

5.2 Development and Transfer of Environmentally Sound Technologies (ESTS)

To combat the causes and impacts of climate change, it is vital to apply environmentally appropriate mitigation and adaptation technologies and strategies. The technological needs assessment revealed that technologies capable of converting urban solid waste to energy, promoting & expanding solar energy, transforming traditional cookstoves into modern/improved and energy saving stoves, and expanding biogas from household level to village level are highly required. Moreover, inputs capable of spreading water in moisture deficient areas, climate–smart agriculture, solar powered drip irrigation, and drought tolerant and early maturing crop varieties are frontline technological needs. Technologies that are helpful for recycling of materials; conserve and use energy efficiently, electric cars, and motor bicycles are identified as key transportation and industry technologicalneeds.

While,biologicalsoilandwaterconservationsupportedbyDeshograss(indigenousgrass to Ethiopia) and promotion of small–scale machinery (2–wheel tractors) to improve planting, harvesting, milling & transportamongsmallholderfarmersarebeingpracticed, invasiveplantspecieslikeProsopisjulifloraand waterhyacintharebeingresearchedfor usage as a domestic energy source.

5.3 Information on Climate Change Research & Systematic Observation Program

For effective climate change research and regular observation, Ethiopia now has installed a network of 1,539 fully functioning meteorological and climatological stations run by NMI (up 386 since the second national communication). Out of the total fully functioning meteorological stations, 1220 are conventional stations, 286 are automatic weather stations, 2 upper air stations, 1 radar, 3 air pollution, and 27 airport electronic stations. In addition, there are 509 (increased by 171 since the second national communication) operational stream gauging stations distributed over the major river basins.

The NMI provides routine information on current climate conditions in the country, including monthly and seasonal climate outlooks. The institute also provides climate information services (CIS), which is seen as one mainstream strategy for climate risk mitigation strategy. Moreover, Ethiopia actively participates in the World Weather Watch (WWW) program of the World Meteorological Organization (WMO) by providing daily weather observations. Ethiopia also cooperates with regional organizations, such as the African Center for Meteorological Applications & Development (ACMAD) & the IGAD Climate Prediction & Application Center (CPAC) in the field of climate & meteorology.

5.4 Information on Education, Training and Public Awareness

The socio–economic effects of climate change are substantial and affect many different facets of society and the economy. While mitigating and adapting to the effects and repercussions of climate change, a rise in young people's climate literacy encourages a shift in attitude and conduct. In this sense, Ethiopia is making strides to include lessons about climate change in the curriculum. With assistance from the United Nations Climate Change Learn, the EFCCC conducted preliminary research on the state of climate change learning in the Ethiopian education sector in 2016. (UNCC).

Higher educational institutions have put substantial efforts into capacity building on climate change by embedding B.Sc., M.Sc, and Ph.D. degree programs in Climate Change. Annual reports submitted to the EFCCC from sector ministries revealed that a series of capacity building training and awareness sessions were offered to their staff and experts along with implementing the CGRE forum to evaluate, share experience, and offer recommendations forimprovements.

5.5 Capacity–Building

The CRGE National Capacity Development Program has done an analysis of institutional and individual capacity shortfalls as well as available capacity for the execution of the CRGE project. According to the program's conclusions, prominent federal government officials, academic and research institutions, media organizations, and Woreda and zonal administration have all received capacity building training on CRGE.

A successful REDD+ MRV system has also been created by collaborating with line ministries, academic institutions, research institutions, and civil society groups. FAO undertook short–term training to build technical capacity of the EFCCC, academic institutions, other relevant line ministries and regional entities.

5.6 Information and Networking

The annual monitoring forum of the implementation of the CRGE plan conducted by the EFCCC has been one of the important in–house networks for exchanging information on climate change. Similarly, many of the Ethiopian policies related to climate change make provision for international collaboration and networking. At national level, strong institutional linkages and communication are established by building a network of stakeholders through electronic means of the government services portal. This will facilitate exchange of information and experience among experts.

CHAPTER ONE: NATIONAL CIRCUMSTANCES

Ethiopia has become a party to the UN convention on climate change after officially ratifying the framework convention on May 31, 1994. As part of its obligation to communicate the progress made on the implementation of the convention in accordance with its commitment, this third assessment report is prepared by building on the previous two communications made to the Conference of the Parties. This chapter provides overarching features and information on the circumstances of the country that characterizes in its physical features, governance, social settings, national development strategies, policies, economic and social developments, the legal and institutional structure,initiativesthatrelate totheactionstakenintheformadaptationandmitigation to tackle climate change in the past years.

1.1. Geographical Setting

Ethiopia, with its total area of approximately 1.1 million square kilometers, is the 8th largest country in Africa and 25th in the World. It occupies a significant part of the Horn of Africa region in North East Africa. Astronomically, it is situated in between 3°N to 15°N latitudes and 33oE to 48oE longitudes. It stretches about 1,639 kilometers from East to West, and about 1,577 kilometers from North to South. Ethiopia lost its access to the sea in the early 1990s and became a landlocked country. About 0.7% of the country is covered by water bodies of inland lakes and rivers. Ethiopia shares borders with Kenya and South Sudan in the South; with Sudan and Eritrea in the West and North; and with Djibouti and Somalia to the East and South East (**Error! Reference source not found.**). The landforms of Ethiopia include mountains, plateaus, the Rift Valley, gorges and plains, which were formed during the Tertiary period of the Cenozoic Era and due to a series of orogeny, volcanism, denudation, pen- plantation, faulting and deposition over thousands of years.

The Great Rift Valley dissects Ethiopia into two distinct highlands in the Eastern and Western escarpments. This has provided a remarkable diversity in climate and landscapes stretching from the Dallo depression of 126 meter below sea level at the northern tip of the Rift Valley to the highest Mountain of Ras Dashen with altitude of 4620 meters above sea level in the Western escarpments. The topography is a complex mix of high rising mountains dominating the highland escarpments, plateaus, valleys and gorges extending from the highlands to the peripheral lowlands. The highlands are generally areas above 1500 masl and the lowlands are those below 1500 masl. The central plateaus are densely settled and cultivated areas extending from 1300 masl to more than 3000 masl, with most mountains rising above 4500 masl (**Error! Reference source not found.**).

Figure 1 Relative location map of Ethiopia in the Horn of Africa

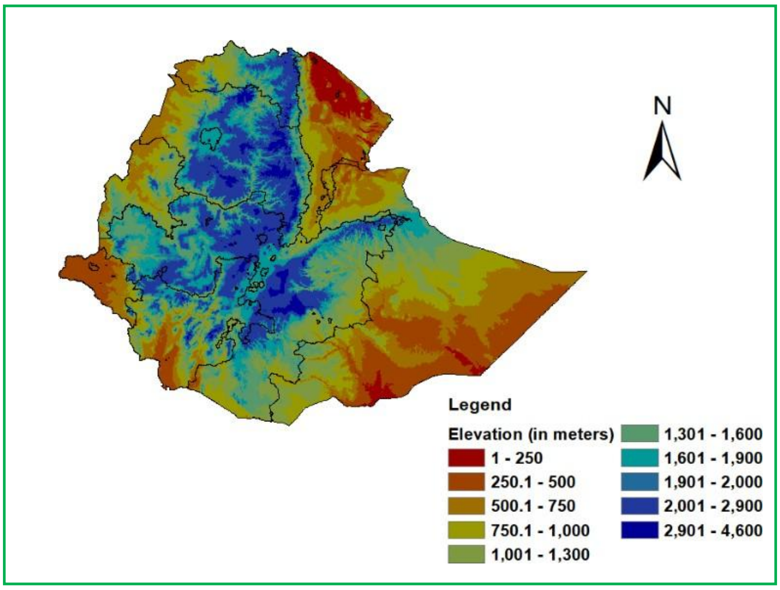

Figure 2 Topographic (Elevation) map of Ethiopia

The plateaus ripple gradually to the lowlands stretching towards Sudan in the West and to the lowlands of Somalia in the East. The Blue Nile (Abay River) flows from the Western highlands crossing through deep gorges and valleys towards Sudan. The South Western highlands harbor one of the last remaining contiguous patches of tropical forests in the country and receive the highest mean annual rainfall from the prevailing winds of the Pacific and Indian oceans. Over 70% of the country falls under the arid climate, in which rainfall is low and temperature is high with high levels of spatial and temporal variability of rainfall.

1.2. History and Culture

Ethiopia is one of the oldest nation states in the world. Its history and existence as a state spanned over 3000 years. Ethiopia cherishes as the place of few of the oldest ancient civilizations that existed in the medieval times. The country is known by the name Abyssinia in old literature encompassing the present-day Ethiopia, Eritrea, Djibouti and beyond. Ethiopia was an important trade route for spices, ivory, gold and other minerals from the East, West and North Africa to the Arabian, Asian and Far East regions through the ports of Adulis, Berbera and Massawa until the late 19th Century. Ethiopia has a long history of wars fought with external aggressors and internal infightings among chiefdoms and kingdoms during its formation. Ethiopia survived as a strong nation state for long and maintained its freedom by detectingcolonialaggressorsin1889G.C.Ethiopiaistheonly uncolonizedcountryintheWorld.Ethiopiaisa countrywithdiverseethnicities,languages, and cultures.

Table 1 List of tangible cultural heritages of Ethiopia registered under UNESCO

No	Name	Location	Year
1	Konso Cultural Landscape	Southern Nations, Nationalities, and Peoples’ Region	2011
2	HararJugol,theFortifiedHistoric Town	Harari Region	2006
3	Aksum	Tigray Region	1980
4	Lower Valley of the Awash	Afar Region	1980
5	Lower Valley of the Omo	Southern Nations, Nationalities, and Peoples’ Region	1980
6	Tiya	Southern Nations, Nationalities, and Peoples’ Region	1980
7	Fasil Ghebbi, GondarRegion	Amhara Region	1979
8	Rock-Hewn Churches, Lalibela	Amhara Region	1978
9	Simien Mountains National Park	Amhara Region	1978

(Source: http://www.moct.gov.et/tourism-master-plan)

Owing to the geographical and agro-ecological diversity, the country is home to a panoramic cultural diversity of over 86 different ethnic/linguistic groups residing in the different agro-ecological regions of the country. The country is the land of origins and a place of rich tangible and intangible heritages. It is a center of endemism for myriads of species and center of origin for several food crops. Ethiopia contributed coffee to the world. The oldest and the first trace of human ancestral remains were discovered in the Hadar Valley of the northern part of the Rift Valley in Ethiopia, making it the origin of humankind, Homo sapiens. Ethiopia is the only country in Africa and one of the few in the world that have their own scripts/alphabets. Ethiopia has registered several of its tangible and intangible heritages under UNESCO's cultural heritage list. A total of 13 heritages, of which 4 are intangible annual festivals (Meskel, Timket, Irreecha and Fichee- Chambalaalla) and 9 tangible World Heritage Sites (eight cultural and one natural sites), have been registered (**Error! Reference source not found.**).

1.3. Governance and Government Structure

The Federal Democratic Republic of Ethiopia has a constitutional federal governance system that has formed a parliamentary governance structure of the republic. The constitution allows establishment of autonomous administrative regional states and provides autonomy to exercise decision making power on regional matters. The Federal Republic of Ethiopia currently comprises 11 autonomous regional states and two chartered city administrations. The federal government and regional state governments have their own respective branches of the three main branches of government: the legislative, the executive and the judiciary. The Federal legislative organ constitutes two houses: the House of People's Representatives (HPR) and the House of Federation (HoF). The highest legislative authority is vested in the HPR whose members are elected by a plurality of votes casted in general elections every five years.

The State Council is the highest organ of the state legislative authority. The highest federal executive power rests with the Prime Minister and the Council of Ministers. The Prime Minister is the chair of the Council and the Commander-in-Chief of the National Armed Forces. The President, on the other hand, is the Head of State. The Federal Supreme Court holds the highest judicial authority of the independent judiciary. The Court's President and Vice President are nominated by the Prime Minister for appointment by the House of People's Representatives. The governance is structured into 22 Ministries, several agencies, commissions and authorities. The Federal Environment Protection Authority is responsible for the coordination, facilitating the implementation of the convention at national level. The regional states administrations represent the EPA in the devolving structure with a similar mandate of coordinating, supervising and monitoring implementation of theconventions.

1.4. Climate characteristics, agroecology and land use

Ethiopia's climate is characterized by a complex and diverse climate pattern with extremely varying distribution of rainfall and temperature. According to the Koppen climate classification, Ethiopia has several distinctly identifiable climate regions in the landscape (

Figure 3 Koppen climate classification map of Ethiopia

). These include the Hot/Arid or warm/desert Climate (Bwh), the Hot/warm Semi-Arid Climate (Bsh), Tropical Savanna Climate (Aw) with distinct dry winter, Tropical Monsoon Rainy Climate (Am) with short dry winter, Warm Temperate Rainy or Subtropical Oceanic highland Climate (Cwb) with dry winter, Warm Temperate Rainy or Oceanic Climate (Cfb) without distinct dry season, Humid subtropical climate (Cwa) and Temperate Mediterranean Climate(Csb).

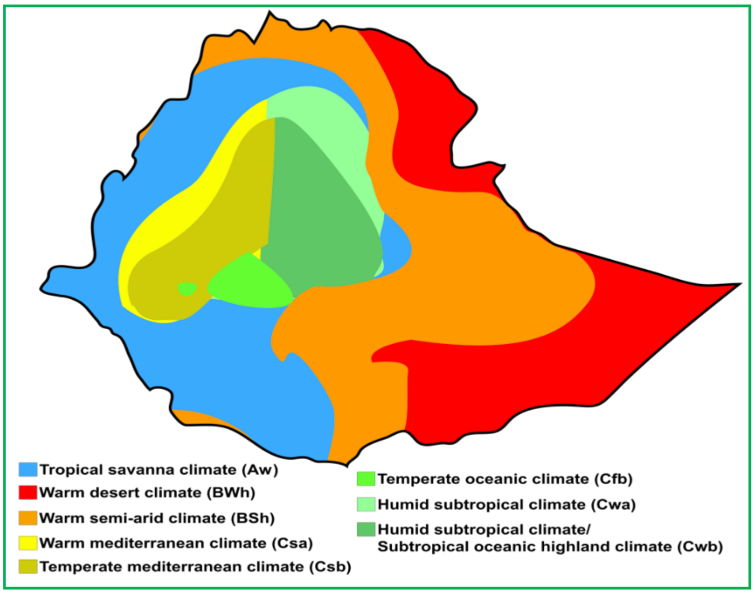

Figure 3 Koppen climate classification map of Ethiopia

1.4.1.Rainfall and Temperature

The seasonal distribution of rainfall is governed by the movement of the prevailing air mass of the Intertropical Convergence Zone (ITCZ), which oscillates across the equator from its northernmost position over northern Ethiopia in July and August, to its southernmost position over southern Africa in December-January. Because of this, there are three rainfall seasons, namely, Bega, Belg and Kiremt. The main rainfall season (Kiremt) from mid-June to mid-September, coincides with the time the ITCZ is at its northernmost position. Parts of northern and central Ethiopia also have a secondary wet season of sporadic and considerably less rainfall from February to May (Belg). The southern regions of Ethiopia experience two distinct wet seasons which occur as the ITCZ passes over the region. The February to May Belg season is the main rainfall season in the southern regions, yielding 100-200 mm per month, while a season with less rainfall (around 100 mm per month) called Bega occurs in October-December. The easternmost corner of Ethiopia receives very little rainfall throughout the year. The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and hence the onset and duration of the rainfall seasons vary considerably inter-annually, causing frequent droughts. The best documented cause of this variability is the El Niño Southern Oscillation (ENSO). Warm phases of the ENSO have been associated with reduced rainfall in the main wet season, causing severe droughts and famine in north and central Ethiopia, but it has also been associated with enhanced rains in the earlier February-April rainfall season, which mainly affects southern Ethiopia.

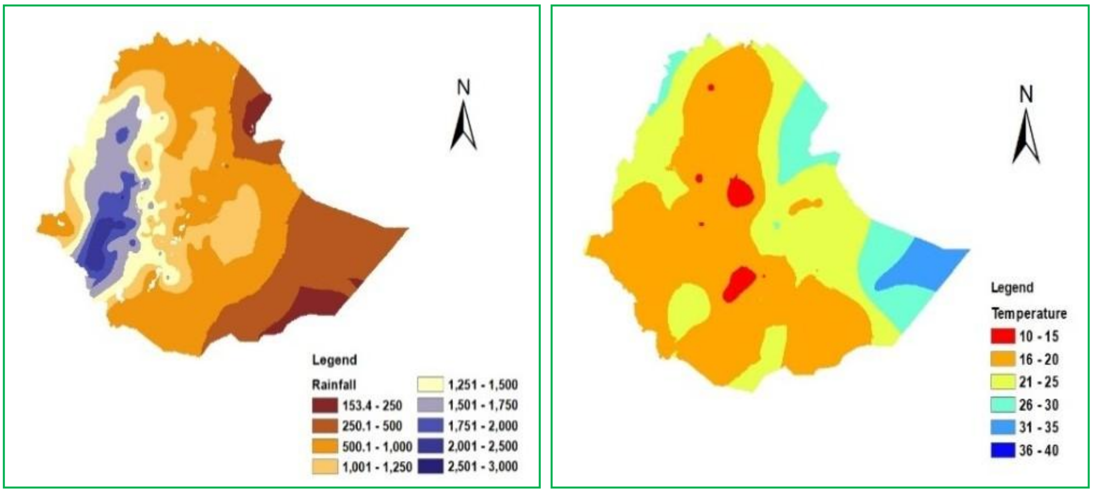

Figure 4 Rainfall and Temperature characteristics of Ethiopia

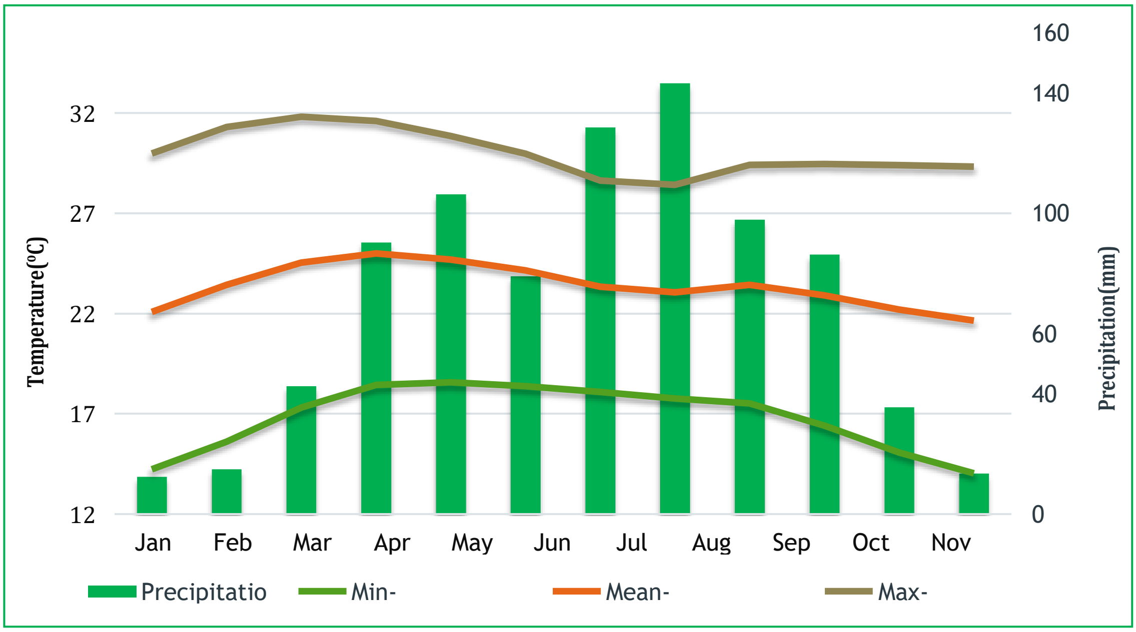

Figure 5 Annual rainfall and temperature distribution of Ethiopia:

*The main rainy season (Kiremt) accounts for 50-80% of the total annual rainfall over the regions having high agricultural productivity and major water reservoirs. Western and northern Ethiopia have monomodal rainfall patterns with the rainfall amount peaking in Kiremt. The temporal distribution in these monomial rainfall areas shrinks from south to north, ranging from over eight months of rain over the southwest to only three months of rain over the northwest. Regions in the Rift valley and adjoining highlands receive bimodal rainfall during Belg and Kiremt seasons. On the other hand, regions of southern Ethiopia experience a bimodal rainfall distribution during the seasons defined as Bega and Belg. These regions have two distinct dry and two distinct wet seasons. The lowlands in the southeast and northeast are tropical, with average temperatures of 25°-30°C, while the central highlands are cooler, with average temperatures of 15°-20°C (**Error! Reference source not found.**,*

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Figure 6 Annual mean temperature of Ethiopia

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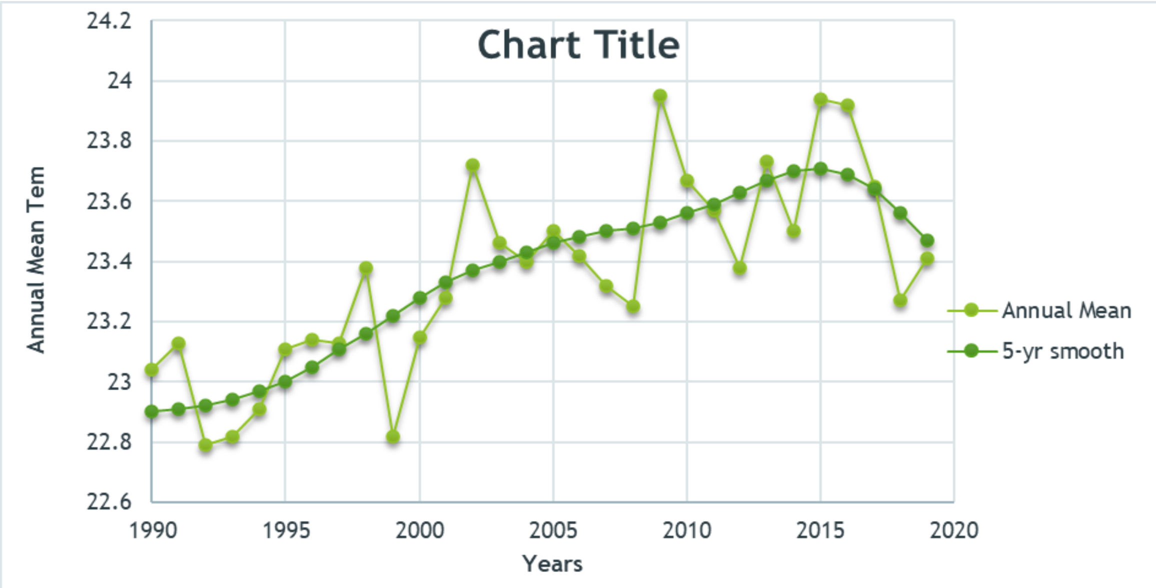

Figure 6 Annual mean temperature of Ethiopia

1.4.2.Climate Change

Climate change is a serious challenge to Ethiopia. The country is one of the most vulnerable and the least ready to overcome the impacts of climate shocks. The vulnerability is due to its exposure to extreme temperature in the arid lowlands and the sensitivity of its ecosystems to climate shocks, and the low economic capacity to effectively respond to climate hazards. In the past decades, the trends show that Ethiopia has been affected by changes in the climate. High variability of rainfall and continuous rise in temperature has been recorded. The mean annual temperature has increased by a magnitude of 0.2°C to 0.28°C per decade in the past six decades (Eshetu el al. 2014). The rise in temperature is most extreme in the hot and arid lowlands. Similarly, the spatial and temporal variability of rainfall has increased in unpredictable ways. In the western highlands, there has been an increase in average annual rainfall while a decreasing trend has been observed in the north eastern highlands in the same period. Rainfall is highly likely to be more unpredictable with expected increase in the frequency of climate extremes. As a result, the country could experience rampant changes in seasonal rainfall distribution. The pattern of the short rainy season could shift both temporally and spatially, which will have a serious impact on food production and rural livelihoods, particularly in the arid and semi-arid lowland regions including the Rift valley.

The projections for the future clearly show that temperature will rise within a range of 0.5°C to 2°C by the 2050s relative to the current state. Not only a rise in temperature but also incidences of droughts and floods have increased in the last 10 years relative to the earlier decades. The social and economic impact relates to the risk of vulnerability. High levels of urban and rural poverty is a key factor for increasing vulnerability to climate change in Ethiopia. The adaptive and coping capacity is weak. In the past, weather variability, extreme events and hazards have resulted in a substantial negative impact on economic growth in agriculture and related sectors. Agriculture alone comprises 45% of total economic output and contributes 78% to employment. However, agriculture is dominated by smallholder subsistence farming, with an average farm size of less than 0.5 hectares, making it very vulnerable to climate change. For instance, droughts reduced the total GDP (Gross Domestic Product) by about 1-4%. Consequently, recurrent droughts and floods have resulted in severe loss of agricultural crops and livestock, undermining the country's foodsecurity.

1.4.3. Agro-ecological zones

The classic or traditional and commonly used category of the agro-ecological regions of Ethiopia identifies six distinct regions based on elevation, temperature and dominant crop types or homogeneityinagriculturalpracticesandlanduses(

Agro-Ecological Zones (Traditional)	Altitude Range	Geographical Regions	Main Crops Grown/Suitability
Kur(Extremecoldand dry highlands)	> 3700 m	Central and Eastern Highlands	Only for grazing
Wurch (Cold and dry highland)	3200-3700	Central and Eastern Highlands	Barley
Dega (Cool andmoist highlands)	2300-3200	Central and Eastern Highlands	Barley, Wheat, Highland oil seeds, Highlandpulses
Woina Dega (mid-highlands)	1500-2300	Central and Eastern Highlands	Wheat, Teff, Barley, Maize, Sorghum, Chickpeas, Field peas, Haricot Beans, Faba Beans, Coffee, Tea
Kola(humidandmoist lowlands)	500-1500	RiftValley,Eastern, Western Southern Lowlands	Sorghum, Finger Millet, Sesame, Cow Peas, Ground nuts,Coffee, Spices, sugarcane
Bereha (Hot and dry lowlands)	<500	AridEastandHumid West Lowlands	MaizeandSorghum,Root cropsinthehumidwest

). This is often used in discussing agricultural production and associated management interventions for major corps growing in the country. Most literature refer the traditional zones, especially the three dominant zones (cool and moist highlands, mid-highlands and dry lowlands) since agricultural production is concentrated in these major zones.

A more elaborated classification of the agro-ecological zones of Ethiopia consists of several sub-zones. The classification is based on temperature, moisture and length of growingperiods(MoA,2000; EIAR,2011).Thelengthofthegrowingperiodinthiscontext isthetotalnumberofdaysinayearduringwhich sufficient moisture is available in the soil to support plant growth. Accordingly, the agro-ecology of the country is divided into 32 different sub-zones with a characteristic feature of agricultural practices and types of cropsgrown(**Error! Reference source not found.**, **Error! Reference source not found.**).Many cropsmaybefoundinseveralzoneswhilesome are restricted to only one or two zones.

Table 2 Traditional classification of the major agro-ecological zones of Ethiopia

Agro-Ecological Zones (Traditional)	Altitude Range	Geographical Regions	Main Crops Grown/Suitability
Kur(Extremecoldand dry highlands)	> 3700 m	Central and Eastern Highlands	Only for grazing
Wurch (Cold and dry highland)	3200-3700	Central and Eastern Highlands	Barley
Dega (Cool andmoist highlands)	2300-3200	Central and Eastern Highlands	Barley, Wheat, Highland oil seeds, Highlandpulses
Woina Dega (mid-highlands)	1500-2300	Central and Eastern Highlands	Wheat, Teff, Barley, Maize, Sorghum, Chickpeas, Field peas, Haricot Beans, Faba Beans, Coffee,Tea
Kola(humidandmoist lowlands)	500-1500	RiftValley,Eastern, Western Southern Lowlands	Sorghum, Finger Millet, Sesame, Cow Peas, Ground nuts,Coffee, Spices, sugarcane
Bereha (Hot and dry lowlands)	<500	AridEastandHumid West Lowlands	MaizeandSorghum,Root cropsin thehumidwest

Table 3 Elaborated agro-ecological zones of Ethiopia

No	Sub Agro-ecology	:a inhectare	% Cover
1	A1 (Hot arid lowland plains)	12 202 265	10.79
2	A2 (Warm arid lowland plains)	22 356 361	19.76
3	A3 (Tepid arid mid highlands)	488 143	0.43
4	H2 (Warm humid lowlands)	2 592 647	2.29
5	H3 (Tepid humid mid highlands)	3 001 630	2.65
6	H4 (Cool humid mid highlands)	926 331	0.82

7	H5 (Cold humid sub-afro-alpine to afro- alpine)	62 620	0.06
8	H6 (Very cold humid sub-afro-alpine)	50 577	0.04
9	M1 (Hot moistlowlands)	672 104	0.59
10	M2 (Warm moist lowlands)	17 109 776	15.12
11	M3 (Tepid moist mid highlands)	9 101 288	8.05
12	M4 (Cool moist mid highlands)	1 963 109	1.74
13	M5 (Cold moist sub-afro-alpine to afro-alpine)	78 829	0.07
14	M6 (Very cold moist sub-afro-alpine to afro- alpine)	15 246	0.01
15	PH1 (Hot per-humid lowlands)	13 088	0.01
16	PH2 (Warm per-humid lowlands)	765 390	0.68
17	PH3 (Tepid per-humid mid highland)	152 281	0.13
18	SA1 (Hot semi-arid lowlands)	449 789	0.40
19	SA2 (Warm semi-arid lowlands)	3 114 607	2.75
20	SA3 (Tepid semi-arid mid highlands)	218 624	0.19
21	SH1 (Hot sub-humid lowlands)	1 893 410	1.67
22	SH2 (Warm sub-humid lowlands)	8 046 859	7.11
23	SH3 (Tepid sub-humid mid highlands)	7 504 025	6.63
24	SH4 (Cool sub-humid mid highlands)	589 049	0.52
25	SH5 (Cold sub-humid sub-afro-alpine to afro- alpine)	68 815	0.06
26	SH6(Verycoldsub-humidsub-afrotoafro-alpine)	34 889	0.03
27	SM1 (Hot sub-moist lowlands)	637 276	0.56
28	SM2 (Warm sub-moist lowlands)	10 890 128	9.63
29	SM3 (Tepid sub-moist mid highlands)	5 850 115	5.17
30	SM4 (Cool sub-moist mid highlands)	1 314 156	1.16
31	SM5 (Cold sub-moist mid highlands)	76 819	0.07
32	SM6 (Very cold sub-moist mid highlands)	18 021	0.02
33	WB (Water body)	870 795	0.77
	Total	**113 129 062**	**100.00**

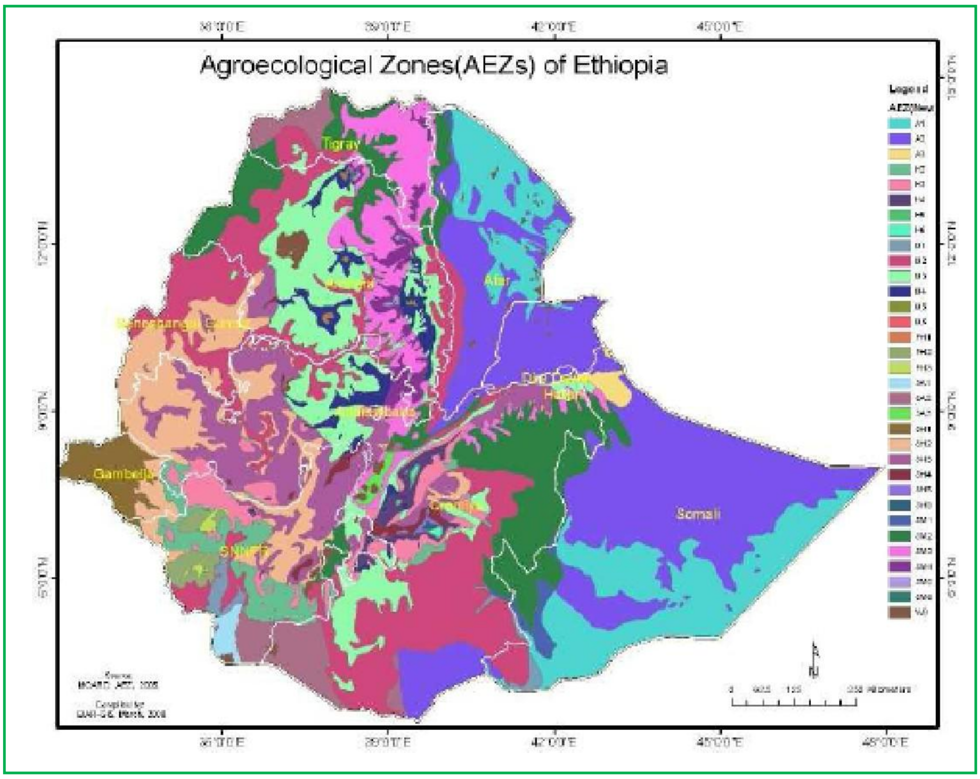

Figure 7 Map of the elaborated agro-ecological zones of Ethiopia

(Source: EIAR, 2011)

1.4.4. Land use land cover and change

The major land use land cover types in the Ethiopian landscape are agricultural land (cultivated land), forest/vegetation, grazing/rangeland, settlements/built up, wetlands/waterbody and baren/degraded lands (**Error! Reference source not found.**). During the last five years, much of the land use change has been from natural to agricultural land use (commercial and smallholder farms), settlement/urbanization and barren/degraded lands (**Error! Reference source not found.**). The rest has been converted to waterbody, grazing land, swamp/wetland, shrubland, and other land uses. The change has been accelerated by anthropogenic factors such as deforestation for agricultural expansion and urbanization.

Table 4 Forest and other land use change 2015-2018 in Ethiopia (area in ha)

Categories	2015	2016	2017	2018
Naturalregeneratingforest(a)	16461.6	16342.2	16223	16103.7
Planted forest (b)	972	1018.26	1064.52	1110.78
Plantation forest	777.6	814.61	851.62	888.63
Introduce species	583.22	608.93	634.64	660.36

Other planted species	194.4	203.65	212.9	222.15
Total forest areas (a+b)	17433.5	17360.5	17287.6	17214.5
Forest and other Land uses				
Categories	2015	2016	2017	2018
Forest	17433.55	17360.5	17287.5	17214.5
Other wood land	22394.33	22394.33	22394.33	22394.33
Other land	72143.7	72216.7	72289.7	72362.7
Total land area	111972	111972	111972	111972

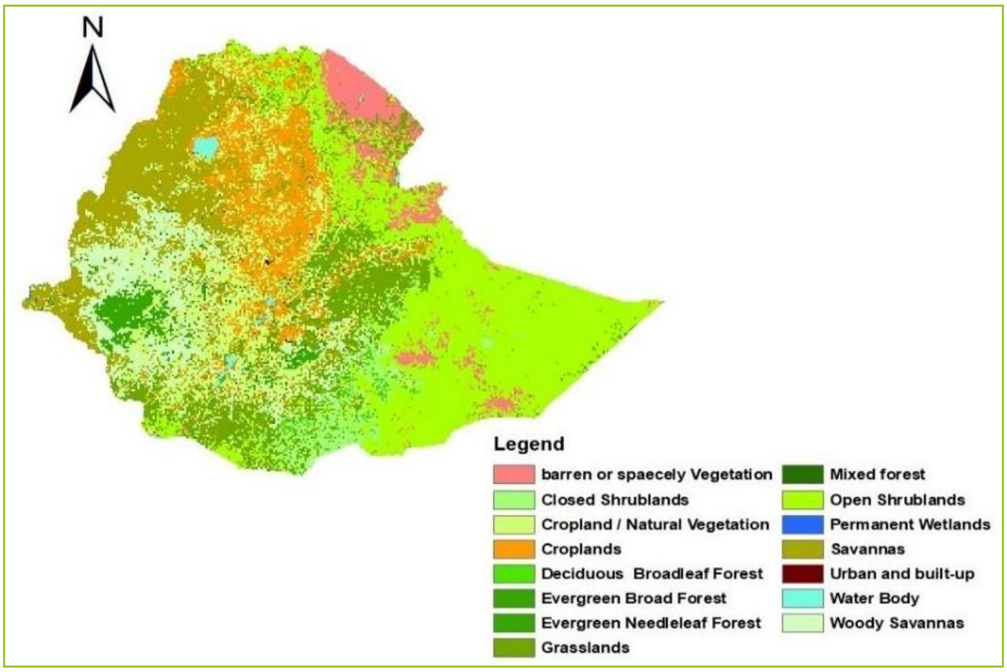

Figure 8 Land use land cover map of Ethiopia (2018)

The forest land, rangelands and the woodlands greatly contribute to the national economy and to rural livelihoods. This is through the provision of timber, fuelwood and non-timber forest products. Forests also provide benefits in the form of food security, health and employment, and support wider ecosystem services (such as water filtration, flood control, and soil retention), which in turn provide economicbenefits.Themaindriver of deforestation is pressure for agricultural land and energy demand.

1.5. Demography and Social Profile

1.5.1.Population

Ethiopia’s population has been increasing rapidly since the 1990s. According to the 1984 Population and Housing Census, the total population of Ethiopia was 53.5 million, of which 86.3 % was rural and 13.7 % urban. By 2007, the total population had increased to 73.9 million; the urban population had risen to 11.9 million and the rural to 62 million. Based on World meter elaboration of the latest UN data and CSA projection, Ethiopia's population is approximately 110 million in 2018. According to the CSA median variant projection (CSA, 2013), the population increased to 94.2 million in 2017, an increase of 20.3 million and is projected to increase to 136 million in 2037. By the end of 2049, Ethiopia's population is projected to surpass 200 million and 293.9 million by the end of 2099 (CSA, 2013).

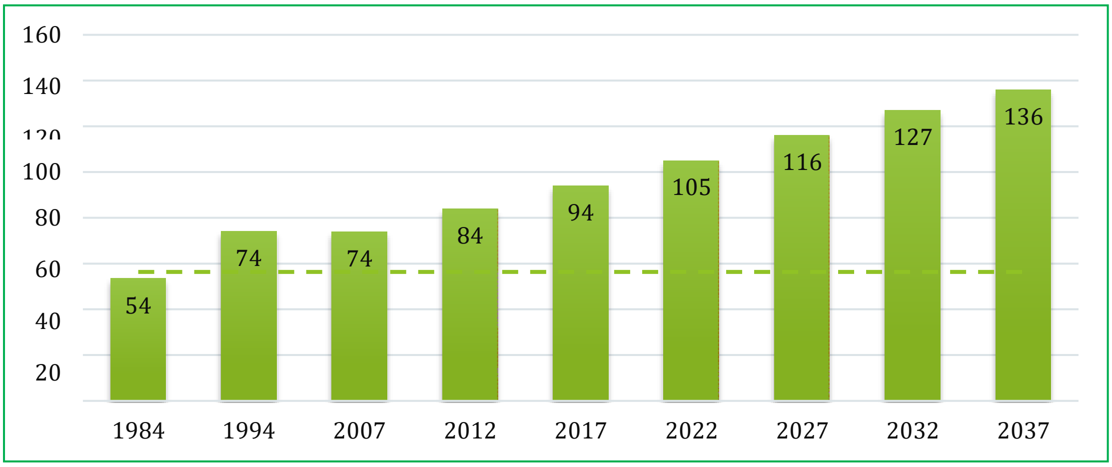

Figure 9 Historical Population Growth of Ethiopia.

Source: CSA 2013 with additional input from other sources

The average annual growth rate of the population was about 3% in the 1990s and declined to 2.9% in the mid-1990s, 2.4% in 2008 and it is currently estimated at 2.3% (CSA, 1984, 1994, 2007,2013).

At the current rate, the population will double in about 30 years. Population density has also been increasing rapidly, from 66 persons/km^2 in 2000 to 84 in 2020. Since the country is predominantly rural, with close to 80% of the population living in rural areas, The increase in population density suggests a decline in the size of farmland and increasing rural to urban migration (CSA, 2013). **Error! Reference source not found.** shows the trend of population growth in Ethiopia.

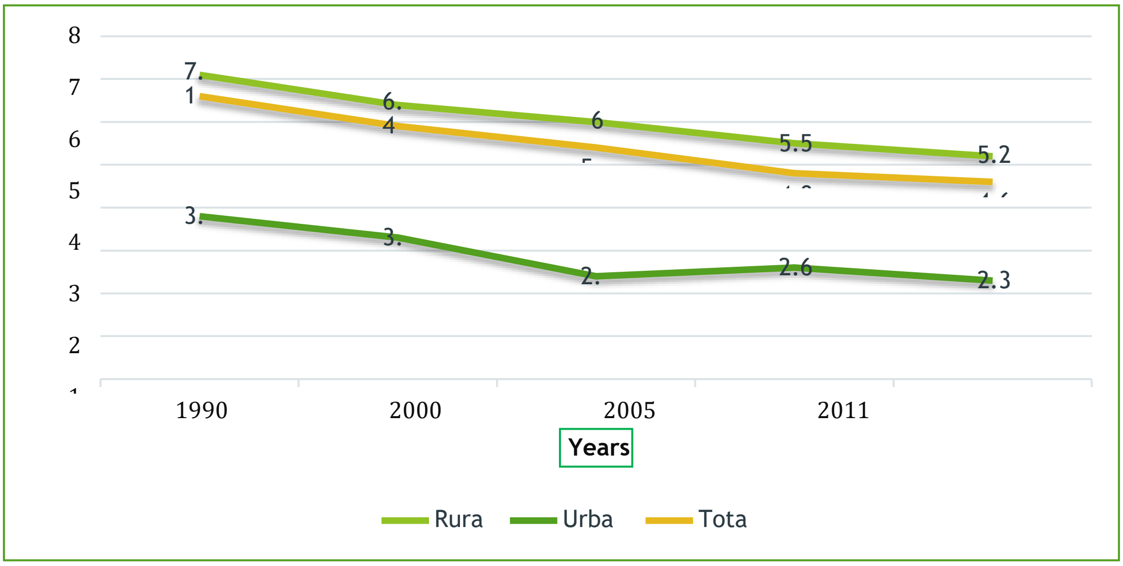

Figure 10 Trend in total fertility by residence (1990-2016).

(Source: CSA, 1984, 1994, 2007, 2013)

The widely used indicator of population size and growth is the total fertility rate (TFR). TFR has declined from an average of 7 children per woman in the early 1990 to 4.6 in 2016. While rural fertility declined from 7.1 children per woman to 5.2, urban fertility, although much lower than that of rural fertility, has declined from 3.8 children per woman to 2.3 children per woman during the same period. According to the 2016 DHS report, TFR is highest in Somali (7.2 children per woman) and lowest in Addis Ababa (1.8 children per woman). Despite the decline, fertility remains one of the highest and has become the major contributing factor for rural population growth. **Error! Reference source not found.** below shows the trends in population growth including the projected population of Ethiopia by 2037.

Notable declines in fertility and mortality rates characterize the recent history of demography in Ethiopia. As a result, the population is maturing more rapidly than other low-income African countries, presenting the country with both opportunities and challenges. The changing demographic pattern means that the country is experiencing a relatively large youth bulge.

Falling fertility rates (and consistent improvements in life expectancy) will cause the population to age, subsequently transitioning Ethiopia into a demographic dividend, a period of accelerated economic productivity that occurs as the number of dependents (children below 15 and people over 64 years of age) declines relative to the working age population (15-64 years). **Error! Reference source not found.** below shows the trends in age structure of the Ethiopian population. As shown in the Figure, while the percentage of economically active age population increases from 51.77 per cent in 2010 to 57% in 2022, the percentage of population aged 0-14 has declined from 45% in 2010 to 40.78% in 2018. The percentage of the old-age population (≥ 65) remains more or less the same. The working-age population (age group 15–64) is projected to rise to 65.7 by 2037 (CSA 2013).

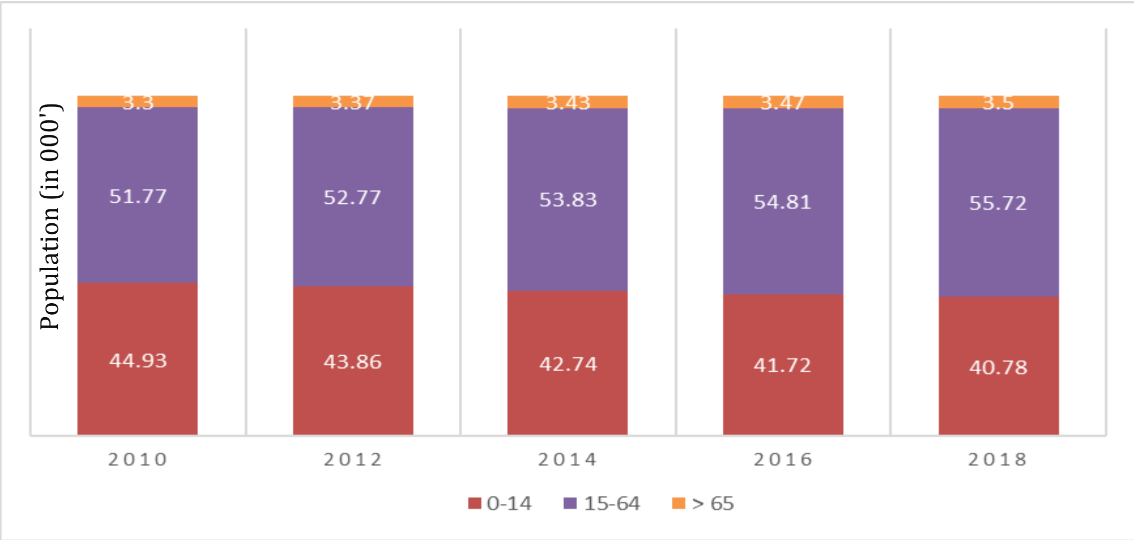

Figure 11 Trends in Age structure (per cent) of the Ethiopian population (2010-2018).

Source: Statical. https://www.statista.com/statistics/455134/age-structure-in-ethiopia/

1.5.2.Urbanization

Ethiopia is the least urbanized country compared to most African countries, with only 22.8% of the people living in urban centers, though this is expected to rise to 31.1% by 2037 (CSA, 2013) and to 40% by 2050. However, Ethiopia has the fastest annual rate of urbanization with 4.5%, which is higher than the Sub-Saharan Africa (SSA) average, i.e., 4% (World Bank, 2014). The urbanization rate is expected to continue at a rate of 5.4% (World Bank, 2015). The urban population increased from 4.5 million in 1984 to 11.86 million in 2007, which is 150 % increase (CSA, 2007). In the same period, the rural population grew from 37.2 million to 61.8 million, an increase of only 66%. The total urban population will more than double over the next twenty years to reach 42.4 million in 2037 (CSA 2013). The main drivers of this rapid urbanization include natural growth, rural to urban migration and reclassification of rural settlements.

Figure 12 Trends of urban population growth in Ethiopia (2007-2037).Source: CSA (2013)

The country is also entering a demographic transition, significantly increasing the youth population and thus the labor force (Hailemariam & Gurmu, 2017). The working-age population (age group 15–64) is projected to rise to 65.7 by 2037 (CSA 2013). Ethiopia thus needs to strengthen the productive and job-creation capacities of its urban centers to accommodate this enormous demand for employment.

Natural growth is a key driver of Ethiopia's urban growth. Between 2008 and 2017, it contributed 35–42% of urban growth, and will continue contributing a little more than one-third up to 2037 (World Bank, 2015). With regard to migration, in 2013 15.1% migrated or moved from place to place, a reduction from 17.8 in 2005. However, the proportion of migrants in urban areas is high, about 44.4. In specific cities, it is even higher as in the case of Semera-Logia (71.6%), Assosa (68.1%), Adama (59.2%), Gambella (58.8%), Bahir Dar (55.6%), and Addis Ababa (47.6%) (CSA 2008). Employment remains the top reason for urban migrants (28.6%) followed by the desire to live with family (25.7%), marriage arrangements (9%), and education (8.4%) (CSA, 2013).

1.5.3.Education

Enhancing education in a country can render broad social and economic benefits. Improved education outcomes lead to improved productivity, increases wages, and powers economic development by improving human capital. The Ethiopian government has given considerable attention and resources to the development of human resources (MoE, 2019). It has taken rigorous measures in successive national development planning processes to improve educational achievement at all levels. Ethiopia has made significant improvements across the education sector since the early 1990s, but along its current path, total educational attainment (for the population aged 15 and older) is still nearly 20% lower than in the rest of low-income African countries. Primary enrolment rates have improved markedly, with net primary enrollment climbing from near 40% in 2000 to 85% by 2014, 94.6% in and 2011/2012. This figurehasreached109.5in2017/2018109.

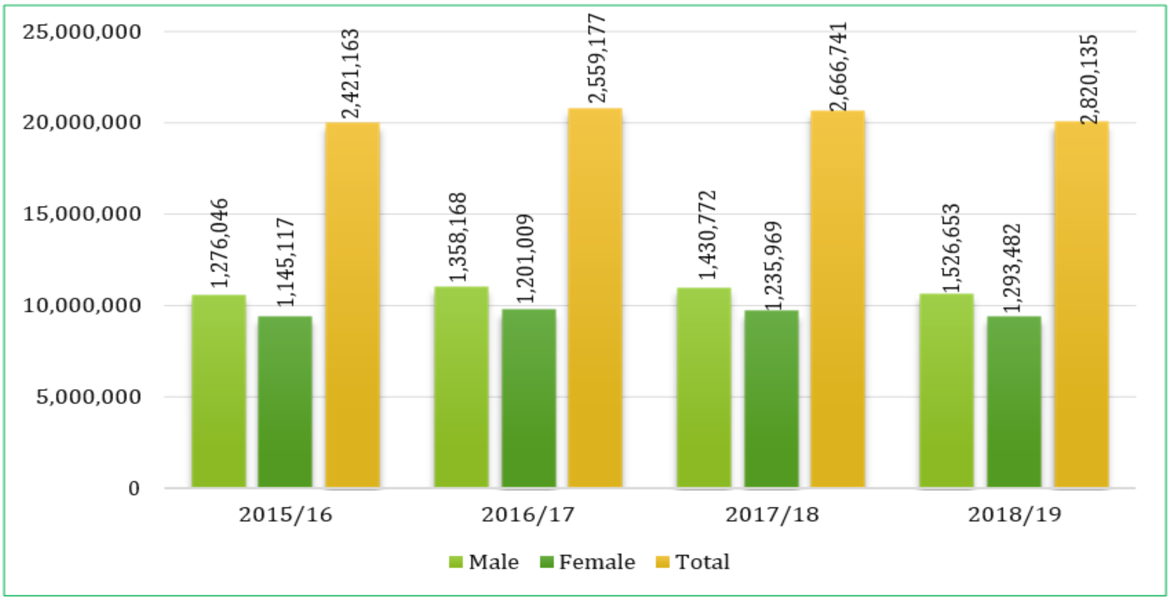

Figure 13 Trends in Gross Enrollment Ration for Grade 1-8, 2011/12-2020/21

Secondary school enrolment and completion, however, has not seen the same rate of progress. In 2000, close to 12% of age-appropriate children were enrolled in secondary education, by 2014 that number had grown to approximately 15%. In other words, over the past 15 years, primary enrolment has increased by more than 110% while secondary enrolment has only increased by around 25%. The number of students enrolled in secondary schools has grown during the last ten years, and enrollment has grown over the past five consecutive years. And the gender gap has decreased significantly from one year to the next. Secondary education offers grades 9 through 12 and covers students between the age of 15 and 18. Moreover, secondary education prepares students for higher education and TVET. As shown in below, the GER of secondary school has increased from 26.3% in 2014/2015 to 32% in 2018/2019.

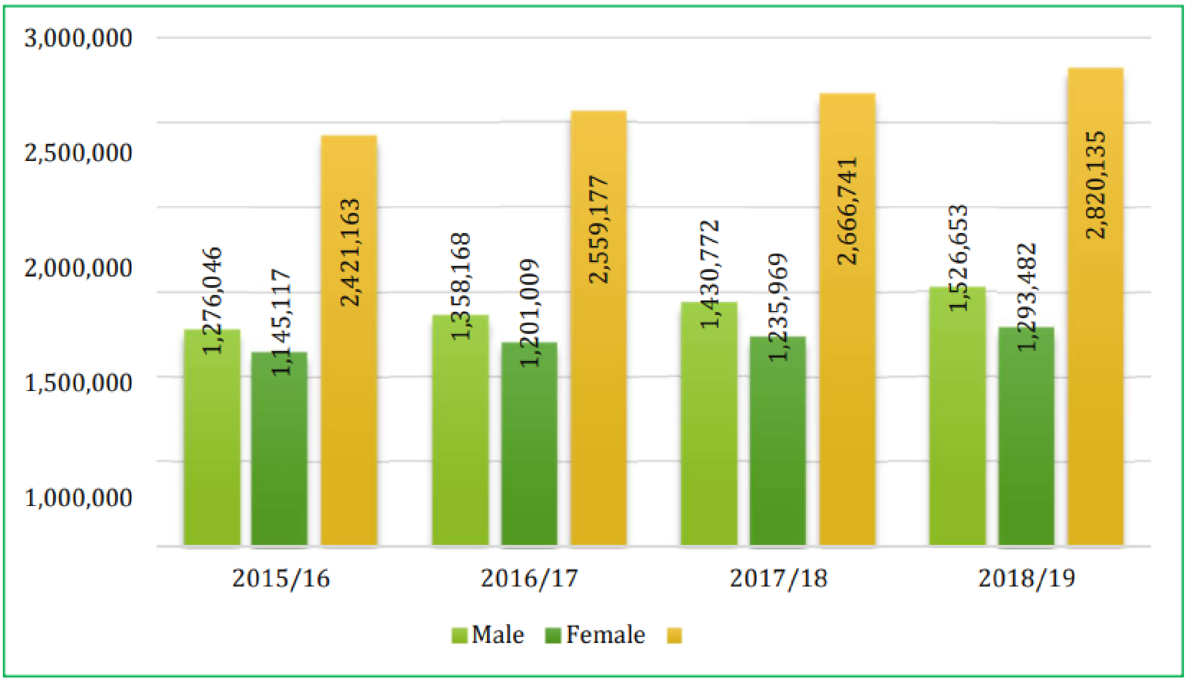

Figure 14 Trends in Gross Enrollment Ratio for Grade 9-12

(Source: FRDE Ministry of Education (2019)

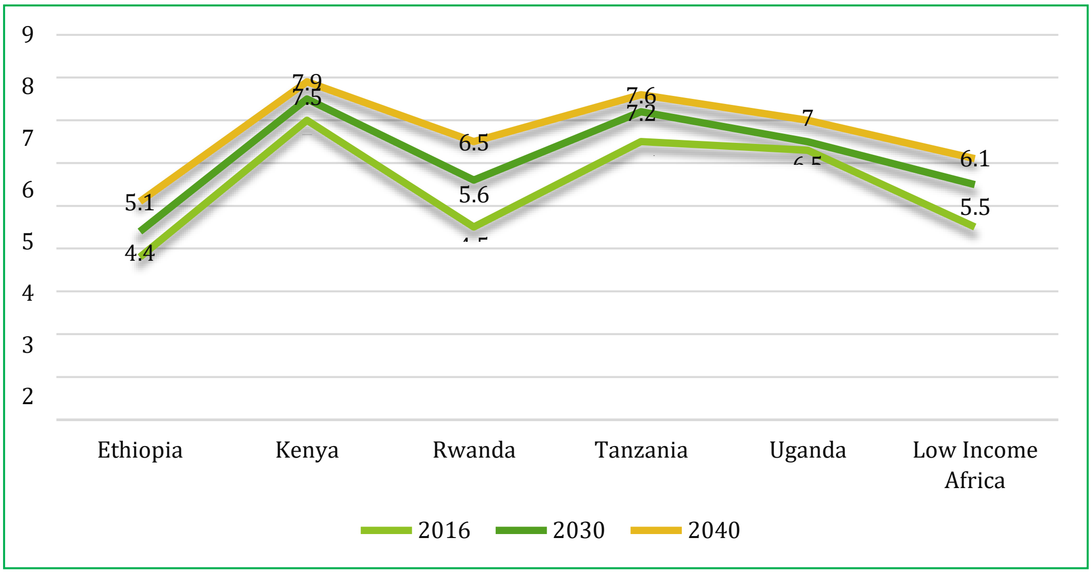

Figure 15 Average years of education (Population 15+), Ethiopia with Regional Peers, 2014-2030.

Source: historical data from UNESCO Institute for Statistics

Average national level of education attainment is a measure of the stock of education access in a country. In 2016, the average years of education for adults (aged 15+) in Ethiopia was 3.8 years, 4.4 years for malesand3.2yearsforfemales.Thisislowerthanthe average attainment for low-income African countries, which stood at around 4.5 years in 2016. Furthermore, when compared with a subset of neighboring countries, Ethiopia’s educational attainment lags far behind. Tanzania, for instance, averaged 6.5 years of education in 2016, which is nearly double Ethiopia’s level. By 2040, average years of education (aged 15+) in Ethiopia are forecast to reach 5.1years, or roughly the level of low-income African countries in 2025 and well below the low-income African countries average of 6.1years in 2040 (Donnenfeld et al., 2017).

1.5.4.Health

Ethiopia's Ministry of Health (MoH) is committed to provide all partners in the health sector, including decision-makers and healthcare service providers, with the most recent health statistics and information (MoH, 2015). The MoH is the major government agency assigned to provide preventive, curative, and rehabilitative health care for the country's population. In addition, the MoH provides primary health care services through a health center with the objectives of accelerating progress toward universal health coverage, protecting people from health emergencies and improving health system responsiveness (MoH, 2015).

Over the past two decades, the GoE and donors have made intensive efforts to extend health infrastructure and services to improve the health of Ethiopians, especially for women and children. Over the last two decades the GoE has established 16,440 health posts and 3,547 health centers and has built 311 hospitals. Ethiopia's health extension programme, which has focused specifically on women and children, has deployed more than 38,000 health extension workers throughout the country (MoH, 2015). Consequently, Ethiopia has made significant advances in many health and mortality related indicators. For instance, life expectancy has increased by 40% and infant mortality has decreased by 60% during the past two decades. Ethiopia has also nearly met Millennium Development Goal 4, registering a 64% drop in under-five mortality. Furthermore, Ethiopia has a relatively low death rate compared to its sub-Saharan African countries, which is largely due to its efforts to control the spread of communicable diseases (especially malaria, TB, and HIV/AIDS). New HIV infections have fallen by 90%, malaria death rates are down 81% and malaria deaths in children under five are down 73% since 1990. Meanwhile, the prevalence of TB has declined by more than 50% over the same time period (MoH, 2015).

While the health gains are remarkable, Ethiopia still lags behind other African countries in many health indicators and faces substantial health and mortality challenges. Ethiopia ranks 150th (out of 186 countries) in infant mortality and 154th in life expectancy. Furthermore, in an absolute sense, Ethiopia still has one of the highest burdens of disease in sub-Saharan Africa. The communicable disease death rate has declined significantly (and is now one of the lowest in sub-Saharan Africa), but the sheer size of Ethiopia's population and the nature of the communicable disease burden (nearly 70% of years of life lost in Ethiopia are due to communicable disease) means that communicable disease detection and treatment will continue to play a major role in the Ethiopian health system for the foreseeable future. Moreover, as communicable disease detection and treatment improves and as Ethiopia continues to develop, non-communicable diseases will play an increasingly deleterious role (Donnenfeld et al., 2017).

Ethiopia has made impressive improvements in infant mortality, maternal mortality and life expectancy over the past two decades. It has exceeded the average life expectancy and infant mortality rates of SSA low-income countries, despite a significant lag relative to the world average. For example, Ethiopia ranks 154th (out of 186) in life expectancy in the world, but ranks 11th (out of 54) in sub-Saharan Africa.

Table 5 Table of selected health indicators, Ethiopia and comparison groups, 2016

Demographic/Health Indicators	Ethiopia	SSA	Africa-Low Income	World
Life Expectancy (years)	65	5961		72
Infant Mortality (per 1000)	46	5956		26
Maternal Mortality (per 100,000)	353	547436		170
Fertility Rate (births over women	4.6	4.95.3		2.4
Contraceptive Use (% of Fertile Women)	36	28.525.8		63.8

Source: Donnenfeld et al., 2017

Ethiopia has decreased infant mortality from 120 deaths per thousand live births in 1990 to 45 in 2016. Currently, Ethiopia’s infant mortality rate (IMR) is 22% lower than that of sub- Saharan Africa and 18% lower than that of other African low-income countries. In 1980, Ethiopia had the 10th highest IMR in Africa, now it ranks 33rd out of 54 African countries. The rate of decline of IMR in Ethiopia has also significantly overtaken its regional counterparts since 2000 (Donnenfeld et al., 2017). Ethiopia has made huge strides in reducing its maternal mortality rate (MMR) (Donnenfeld et al., 2017).

Over the last three decades, the MMR in Ethiopia has fallen from 1,250 (per 100,000 live births) to 353, which represents a 70% decrease in 2017. Ethiopia’s MMR in 2015 is 35% lower than the average for sub-Saharan Africa and 25% lower than the average for other low-income African countries. Within the region, Ethiopia ranks 3rd in MMR, behind Uganda and Rwanda, but ahead of Tanzania and Kenya. These improvements in IMR and MMR reflect a concerted effort made by the Ethiopian Government and the international aid community to improve health outcomes for women and children, primarily through the Ethiopia Health extension programme (MoH, 2005). Over 2,500 health centers and 12,000 health posts offer community case management services to millions of Ethiopians, meanwhile immunization coverage and maternal antenatal care service have expanded significantly (MoH, 2015). The rapid decrease in infant mortality, paired with increases in contraceptive use, has led to a rapid drop in Ethiopia’s fertility rate (Donnenfeld et al., 2017). A look at life expectancy shows that Ethiopia has outperformed its regional counterparts in life expectancy gains since 1990. Ethiopia had the lowest life expectancy of the group in 1990 (46 years), but it is now ranked 3rd (65 years), just below Rwanda and Tanzania (Donnenfeld et al., 2017).

In summary, Ethiopia's economic development has been accompanied by rapid decreases in infant mortality and commensurate improvements in life expectancy. But it is important to recognize that Ethiopia still has a long way to go to reaching middle- income levels of infant mortality, maternal mortality, and life expectancy. Thus, it is important that Ethiopia prioritizes continued improvement in these areas to foster a healthy and productivepopulation.

1.5.5.Water Supply and Sanitation

Achievements from a very low base, access to improved water and sanitation is rising rapidly. Ethiopia has also made rapid progress on improving access to clean water, but still lags behind much of the world. At 57% access to improved water sources, Ethiopia still has one of the lowest access rates in the region. According to the 2016 DHS, about 65% of the households in Ethiopia have access to improved sources of drinking water. Indeed, there is variation between rural and urban. While about 97.3% of the urban households get drinking water from improved sources, it is only 56.5% of the rural households who are able to get drinking water from improved sources. While about 63% of the urban households get improved water from water piped into dwellings, it is only 1.8.% of the rural households who get improved water from water piped into dwellings/yard. The majority of rural households get water from unimproved sources.But this figure is only 2.7% for urban households (CSA & ICF, 2017).

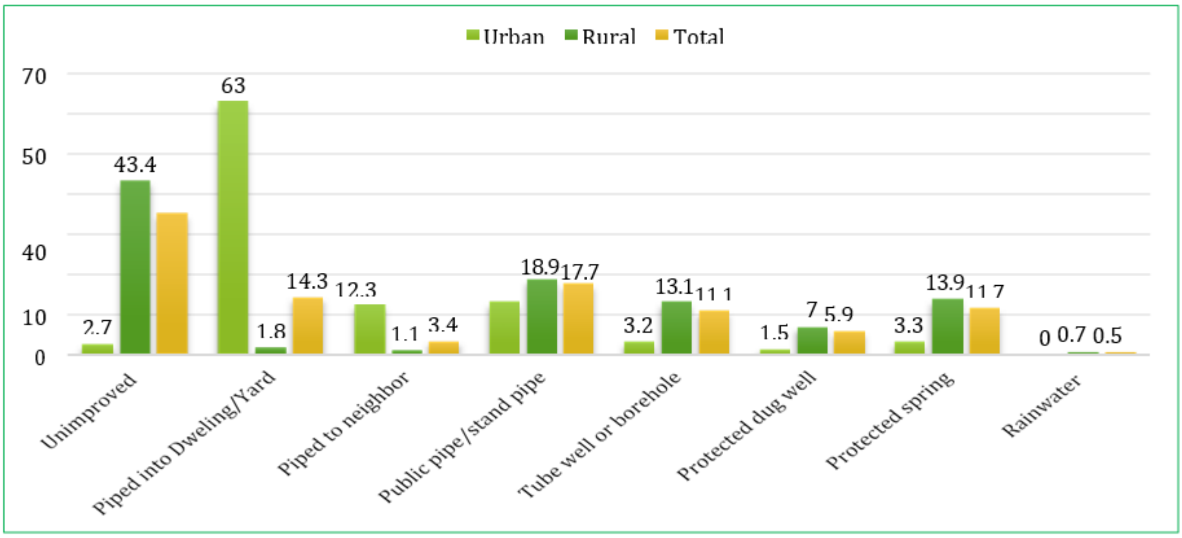

Figure 16 Percentage distribution of households by source of drinking water, 2016.

(Source: The 2016 Demographic and Health Survey)

Ethiopia has also made more rapid progress on access to improved sanitation than any other African country from 2000 to 2015, improving access by roughly 19 percentage points. Despite that progress, Ethiopia ranks 32nd among 54 African countries and 162nd in the world in terms of the percentage of its population with access to improved sanitation facilities (Donnenfeld et al., 2017). As shown. Below, it is only 6.3% of the households who are using improved sanitation in 2016. The majority, i.e., 93.7% are using unimproved sanitation. There is a difference between rural and urban residence in terms of access to sanitation facilities. While 16% of the urban households use improved.

Toilet facilities and waste disposal are the two important forms of sanitation. There are two forms of toilet facilities-improved and unimproved. Improved toilet facilities include any non-shared toilet of the following types: flush/pour flush toilets to a piped sewer system, septic tank, pit latrine, or unknown destination; ventilated improved pit latrines; pit latrines with slabs; and composting toilets. On the other hand, unimproved toilet facilities include any toilet of the following types shared by two or more households: flush/pour flush not to a sewer/septic tank/pit latrine, pit latrines without slabs/open pits, buckets, hanging toilets/hanging latrines, and others. According to the 2016 DHS, only 8.5% of households use improved toilet facilities (34.6% in urban areas and 1.8% in rural areas). More than half (56%) of rural households use unimproved toilet facilities.

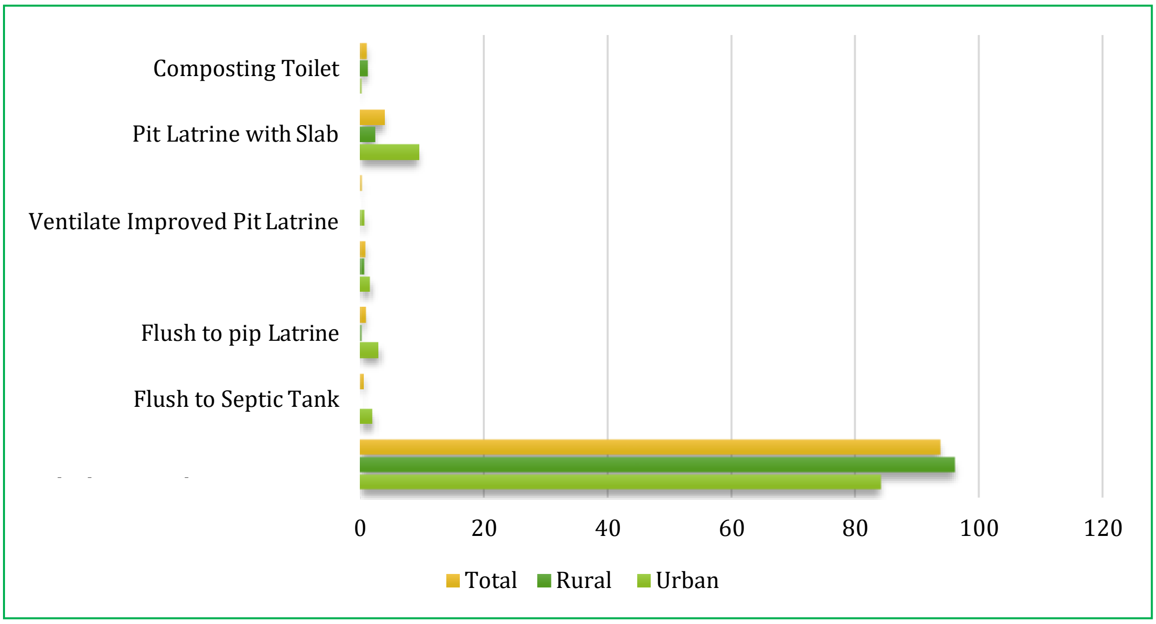

Figure 17 Percentage distribution of households by type of sanitation facility, 2016.

(Source: The 2016 Demographic and health survey)

About 32% of the households in Ethiopia have no toilet facility (38.8% in rural areas and 6.9% in urban areas). They defecate in open fields

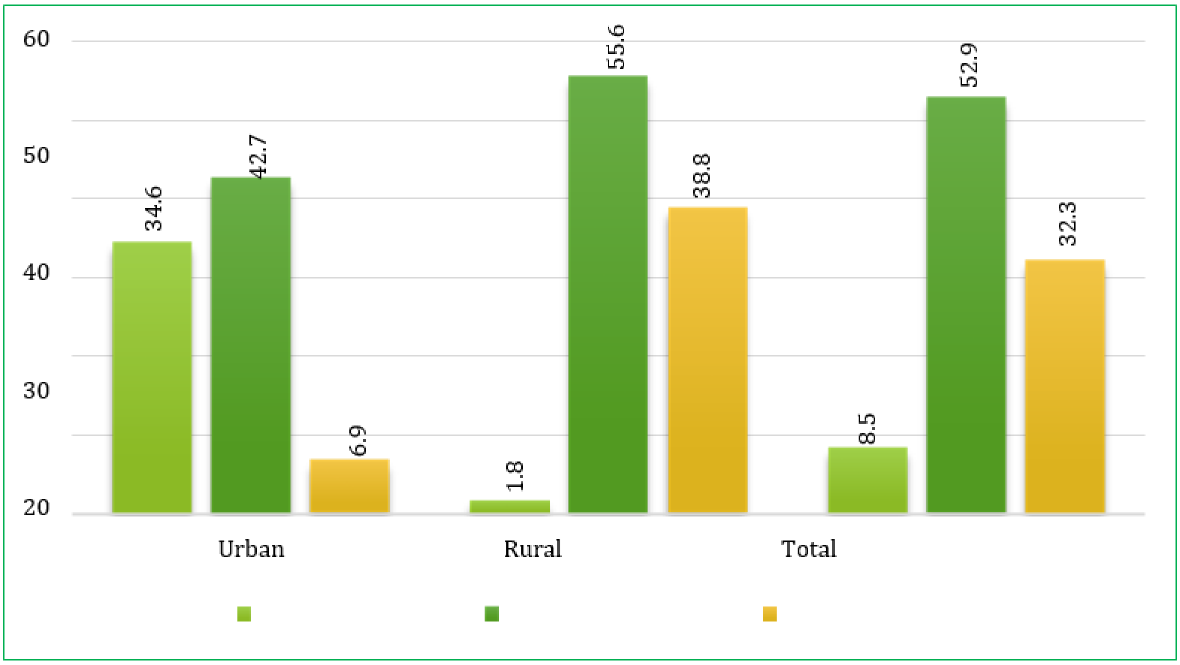

Figure 18 Percentage distribution of households by residence and type of toilet facilities.

(Source: Demographic and Household Survey, 2016

1.6. Economic Profile and Infrastructure

1.6.1.Agriculture Sector

Total cultivated land for crop production slightly increased by 1.1 % to 12.9 million hectares, of which cereals production covered 81.5 % pulses 12.2 percent and oilseeds 6.4 percent (**Error! Reference source not found.**). Total grain production reached 335.2 million quintals, of which cereal production accounted for 88.5 percent, while pulses and oil seeds comprised 11.5%. Cereals and oilseeds production increased by 6.9 and 7.3 percent over the preceding year owing to 1.2 and 9.8 % expansion in cultivated land area respectively. In contrast, production of pulses marginally declined by 0.2 % as a result of 3.5 percent contraction in cultivated land area (**Error! Reference source not found.**).

Table 6 Estimates of agricultural production and cultivated areas of major grain crops for private peasant holdings-Meher Season

Agricultural Production	**2016/17**		**2017/18**		**2018/19**	
	Cultivated Area	Total Production	Cultivated Area	Total Production	Cultivated Area	Total Production
Cereals	10219	253847	10232	267789	10358	277638
(Annual %	2.5	9.8	0.1	5.5	1.2	3.7
Change)	0	0	0	0	0	0
Pulses	1550	28146	1598	29785	1620	30113
(Annual %	-6.2	1.6	3.1	5.8	1.4	1.1
Change)	0	0	0	0	0	0
Oilseeds	805	8392	846	8550	747	7850
(Annual %	-6.3	6.9	5.1	1.9	-11.7	-8.2
Change)	0	0	0	0	0	0
Total	12574	290386	12676	306124	12727	315602
(Annual %	0.7	8.8	0.8	5.4	0.4	3.1
Change)	0	0	0	0	0	0

(Source: Central Statistical Agency (CSA) 2016-2020)

This sector contributes 32.7 percent of agricultural GDP in 2019/20 (**Error! Reference source not found.**). Ethiopia has the largest livestock population in Africa. Like agricultural cropping, livestock cultivation is mainly based on either mixed farming or pastoralism. Ethiopia's livestock population is the largest in Africa, with 60 million cattle, 31.3 million sheep, 32.7 million goats, 1.4 million camels (downward trend) and 56.9 million poultry (**Error! Reference source not found.**). About 70% of the cattle and sheep and 30

% of the goats are in the highlands above 1,500 m. All camels are in the lowlands. Most cattle breeds (99) are indigenous and just 1 % are hybrids. The cattle population is expected to increase by almost 30 % by 2030 under business-as-usual assumptions, resulting in increased emissions (**Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**).

Table 7 Sectoral Contributions to GDP and GDP Growth

Items		2015/16	2016/17	2017/18	2018/19
Sector	Agriculture	544.1	580.4	600.9	623.8
	Industry	343.9	413.8	464.4	526.2
	Services	575.9	619.3	673.9	745.7
Total		1,463.9	1,613.5	1,739.3	1895.7
Less FISIM		14.5	14.5	17.0	19.8
Growth in Real GDP		8.0	10.1	7.7	9.0
Share in GDP (in %)	Agriculture	37.5	36.3	34.9	33.3
	Industry	23.7	25.9	27.0	28.1
	Services	39.7	38.8	39.2	39.8

(Source: National Bank of Ethiopia)

Table 8 Livestock number per year of Ethiopia

Year	2013/14	2016/17	2017/18
Cattle	55027280	59500000	60390000
Sheep	27350000	30700000	31300000
Goat	28160000	30200000	32740000
Horse	1960000	2160000	2010000
Donkey	6950000	8440000	8850000
Mule	360000	410000	460000
Camel	1100000	1210000	1420000
Poultry	51350000	56530000	56060000
Beehive	5052297	6189329	6523969

(CSA, 2013-2018)

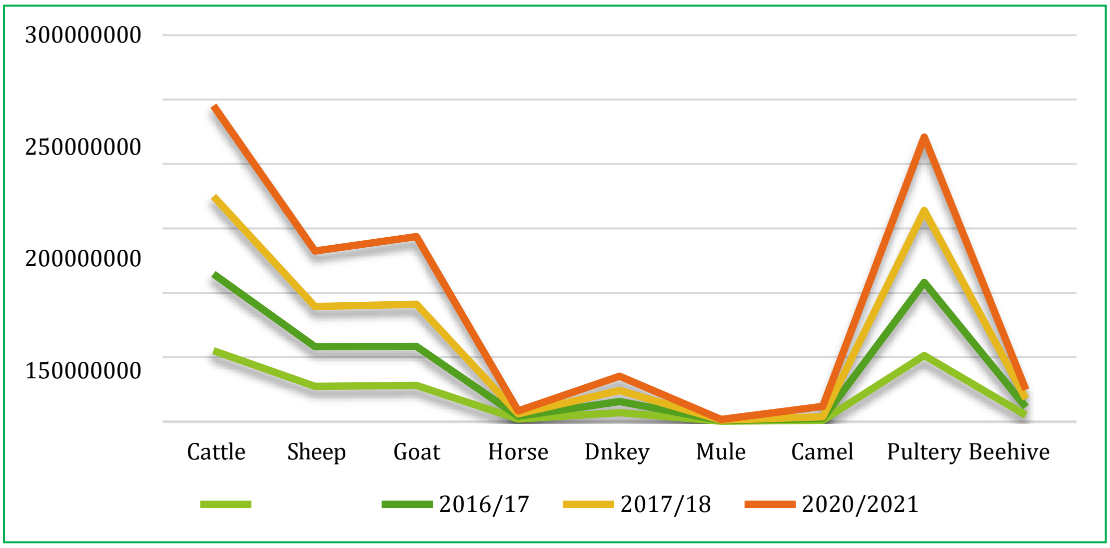

Figure 19 Livestock number per year in Ethiopia (Source: CSA 2013-2018)

Table 9 Livestock number distribution in regions per year

	2013/14			**2016/17**		
Region	Cattle	sheep	Goats	Cattle	sheep	Goats
Tigray	4298023	1481963	4000252	4791341	2041731	4584138
Afar	1359908	1474618	2984271	1315917	1729159	3461260
Amhara	14225988	8518066	5291571	15982541	10735926	6438600
Oromia	22505219	9493622	8151014	24144361	9866172	8129784
Somalia	610898	1420767	2033165	584983	1022298	1519602
Benshangule-Gumuz	604563	83825	417424	777915	100013	431216
SNNP	11044147	4748676	4953588	11485147	5087007	5258250
Gambela	276246	45428	89860	282654	44302	99018
Harari	57258	8401	58432	69387	7100	72555
Dire Dawa	45030	72565	183755	52421	64234	205804
	2017/18					
Region	Cattle	Sheep	Goats			
Tigray	4817101	2172938	1301221			
Afar	1317139	2081955	3265403			
Amhara	16148390	11086083	7766661			
Oromia	24432974	9394430	8591204			
Somale	589503	1360703	2826424			

Benshangule-Gumuz	795024	160029	602840				
SNNP	11883548	4639606	4958255				
Gambela	285102	35285	107083				
Harari	72277	6896	69901				
Dire Dawa	51958	61332	249393				

(Source: CSA 2013-2018)

1.6.2.Manufacturing Industry

Industrial development in Ethiopia is extremely low. The low level of development of the industrial sector is an indication of the low-level development of the Ethiopian economy. In the modern world development is equated with industrialization. Ethiopia's manufacturing sector is small, even by African standards. For over 20 years, the share of manufacturing value added in total value added in Ethiopia has varied between 4 and 5 (Teferi et al, 2019). Compared to other countries in sub-Saharan Africa (SSA), this is a very modest contribution. Like many other African countries, the industrial sector in Ethiopia is characterized by a large number of very small, typically informal, enterprises and a small number of large firms that account for the bulk of manufacturing output and employment. Micro and small firms tend to record low value added, low wages, virtually no exports, and little technological progress (Shiferaw & Bedi, 2013). The structure of the manufacturing sector, in particular the concentration of activity in very small firms and the small number of large firms, is an important reason for the modest contribution of manufacturing to Ethiopia's economy (Donnenfeld et al., 2017).

Beginning in the mid-2000s, Ethiopia's ADLI strategy was supplemented with investment in various light manufacturing sectors, with mixed effects. In some areas (i.e. cut flowers), the strategy was successful, and in other areas (i.e. agribusiness and leather processing), it was less successful. The manufacturing industry has averaged 10.9% growth per year since 2004, but has fallen significantly short of the GTP goal of 22% growth annually. Manufacturing growth barely kept up with Ethiopia's overall economic growth rate, so as a share of GDP the manufacturing sector has hovered around 4.5% over the past decade (Donnenfeld et al., 2017).

The GTP II outlines a plan to push manufacturing and industry to jump-start industrialization in Ethiopia and follow the development path of China and the East Asian Tigers by moving workers from agriculture into higher value-added manufacturing activities. However, Ethiopia faces significant barriers to manufacturing growth. First, while labor productivity in Ethiopian firms is generally on par with low-income peers, it is propped up by high capital intensity rather than human capital contributions (AfDB, 2014). Second, the business environment for Small and Medium Sized Enterprises (SMEs) and other private firms is hindered significantly by low access to finance, unreliable supply of electricity, and lack of access to the land (AfDB, 2014). A lack of credit for SMEs hinders productivity and constrains their ability to scale up. Finally, electricity shortages and land constraints (due to lengthy wait times and complicated application processes) complicate firms' ability to operate in a smooth and efficient manner. Indeed, Ethiopia's industrial base and economic development are the lowest even by African standards. There are various constraints to the country's industrial development. However, the potential for industrial development is also enormous (Teferi et al., 2019). The constraints and opportunities for industrial development are indicated in

below.

Table 10 Challenges and opportunities of industrial development

Challenges	Opportunities
High logistics and transportation cost	Relatively cheap electricity charge in comparison to other African countries.
Limited research/study and action on export incentives and market	Macroeconomic stability and rapidly growing economy
Low labor productivity	Relatively cheap labor force & increasing number of trainedemployees
High cost of imported raw materials	Access to a wide market (large domestic market, COMESA, AGOA, EBA opportunities, China market etc.)
Limited compliance to the international requirements and market	Competitive incentive packages which include export incentives.
Underdeveloped rural infrastructure in the potential areas	Integrated Agro-Industrial Parks (one stop shoppingforallthe services,economiesofscale, extension services, development of common infrastructure)
Weak supply chain integration, market institutions and information system	Global attention due to its remarkable economic growth and credit worthiness
Low level of technology	

Source: Teferi et al., 2019.

1.6.3.Trade

As the Ethiopian economy is an agrarian economy its merchandise export is determined by agricultural products. According to the data from National Bank of Ethiopia, for all study periods the export structure of Ethiopia has been characterized by greater concentration of few traditional exports such as coffee, oil seeds, and pulses and chat. Coffee dominates the total merchandise export item of the country and accounts for 29.5% of visible export earnings. Oilseeds accounting for 14.9 % take the second position followed by pulses 9.5 %, and chat 9.5 % (Teferi et al., 2019).

Table 11 The share of export items in the total merchandise export value.

(Source: National Bank of Ethiopia, 2018

Particulars	2015/16	2016/17	2017/18
	% Share	% Share	% Share
Coffee	25.2	30.4	29.5
Oilseeds	16.6	12.1	14.9
Leather and Leather products	4	3.9	4.7
Pulses	8.1	9.6	9.5
Meat & Meat Products	3.4	3.4	3.6
Fruits & Vegetables	1.9	1.9	2.2
Live Animals	5.2	2.3	2.2
Chat	9.2	9.4	9.3
Gold	10.1	7.2	3.5
Flower	7.9	7.5	8
Electricity	1.1	2.5	3
Others	7.4	9.7	9.7
Total Export	100.0	100.0	100.0

Particulars	2015/16	2016/17	2017/18
	% Share	% Share	% Share
Coffee	25.2	30.4	29.5
Oilseeds	16.6	12.1	14.9
Leather and Leather products	4	3.9	4.7
Pulses	8.1	9.6	9.5
Meat & Meat Products	3.4	3.4	3.6
Fruits & Vegetables	1.9	1.9	2.2
Live Animals	5.2	2.3	2.2

Chat	9.2	9.4	9.3
Gold	10.1	7.2	3.5
Flower	7.9	7.5	8
Electricity	1.1	2.5	3
Others	7.4	9.7	9.7
Total Export	100.0	100.0	100.0

Ethiopia's volume of trade has expanded rapidly over the past two decades. Since 2003, Ethiopia has increased the value of total exports over fivefold. Exports of goods have doubled in nominal terms every four years since 2001, which translates to a 20% average annual growth rate (Donnenfeld et al., 2017). This growth was helped by high commodity prices, notably for coffee, gold, and oilseeds, which make up the majority of Ethiopia's export basket. Meanwhile, service export was largely driven by the growth of Ethiopian Airlines, the country's flagship airline carrier. Over the same time period, imports have also grown. Ethiopia's public investment strategy resulted in high demand for significant quantities of capital and construction equipment, leading to a persistent trade deficit of between 16% and 22% over the past decade. The trade deficit in 2018 sits at about 18% of GDP, which is a bit higher than the African low-income average and significantly higher than regional peers. Along the current path, the trade balance will improve in the short term, before growing to 22% of GDP by 2030 (Donnenfeld et al., 2017). The short- term reduction in the deficit is derived from anticipated energy exports from the GERD, while the long-term downward trend tracks with the forecast of an increase in agricultural import dependence.

A heavy reliance on primary product exports, massive investment in public infrastructure, and rising agricultural import dependence mean that Ethiopia is unlikely to improve its trade balance significantly along the current path. Ethiopia's export sector is also hampered by an overvalued exchange rate and poor trade logistics, making Ethiopian goods more expensive compared to other low-income economies. Efforts to diversify exports within and across sectors will help Ethiopia increase its export value and protect against adverse commodity shocks (Donnenfeld et al., 2017). Alike the commodity structure, the country's exports has been concentrated geographically with the largest proportion of exports destined to limited markets. The major export destinations for Ethiopian goods show that Asia accounted for 40 % of Ethiopia's export earnings followed by Europe (28%). On the other hand, about 20.9 % of Ethiopia's export earnings originated from markets in Africa (Teferi et al., 2019) (

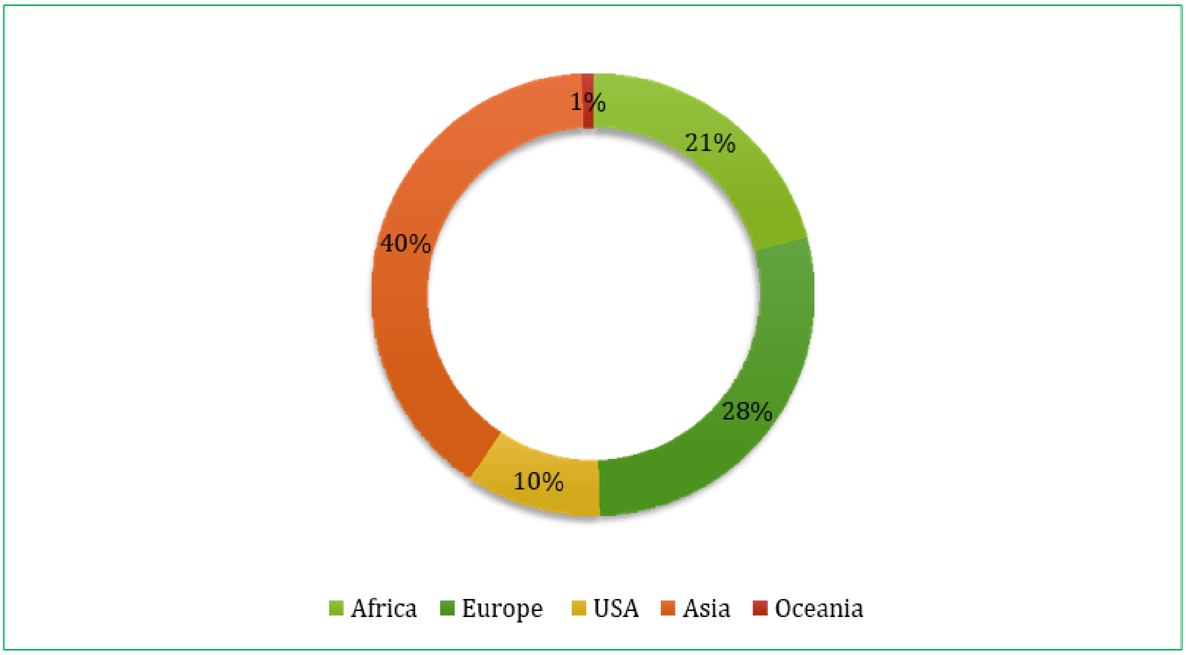

Figure 20 Export markets for Exports for Ethiopian commodities.

Source: Teferi et al., 2019.

Looking at the direction of trade by individual countries, five countries (China, USA, Netherlands, Saudi Arabia and Djibouti) are important which account for 39% of Ethiopia's exports in 2015/2016. With regard to imports of goods, during 2017/18, Asia accounted for 64.2 percent of the total imports of Ethiopia followed by Europe (19.3 %). Ethiopia's total imports with the USA accounted for 9.4 % of the total import bill. About 51% of Ethiopians merchandise import originated from China, USA, Japan, Italy, and USA (Teferi et al.,2019).

1.6.4.Transport

Transport service plays a key role in the implementation of national development plans. Large scale agricultural development, industry, mining and any socio-economic projects can be implemented only if there exists a properly functioning transport infrastructure. As Addis Ababa is an important regional and international transport hub, the road network radiates from Addis Ababa to the regions, linking it with important cities, towns and to agriculturally, commercially and industrially active centers of the country. International highways also link Addis Ababa and other cities and towns with neighboring countries such as Kenya, Djibouti, Eritrea and Sudan (Aklilu, 2005; Worku, 2010).

Today most passengers and goods in Ethiopia are transported by road transport. In Ethiopia road transportation is relatively a recent phenomenon. Italians basically started it during their period of occupation. These roads were essentially built for military movement purposes. In other words, they were not built for the purpose of economic integration of the country. Later on, with Addis Ababa growing as the political center of the country, the roads built in subsequent periods were constructed for administrative connections (Teferi et al., 2019). The radial patterns of network development with the center being Addis Ababa, exhibits administrative integration rather than economic integration.

This, however, does not mean that the roads were not used for economic purposes.Dataobtainedfrom the Ethiopian Roads Authority showed that during 2004/05 classified road network (in Ethiopia was 37,018 km while the total road network increased rapidly and reached 126,773 km during 2017/18 (this includes 35,958 km rural road (28.3%). The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads (Teferi et al., 2019). As shown in **Error! Reference source not found.**, the total road network has shown an increasing trend. As of 2011/12, the growth in the road network was significant.

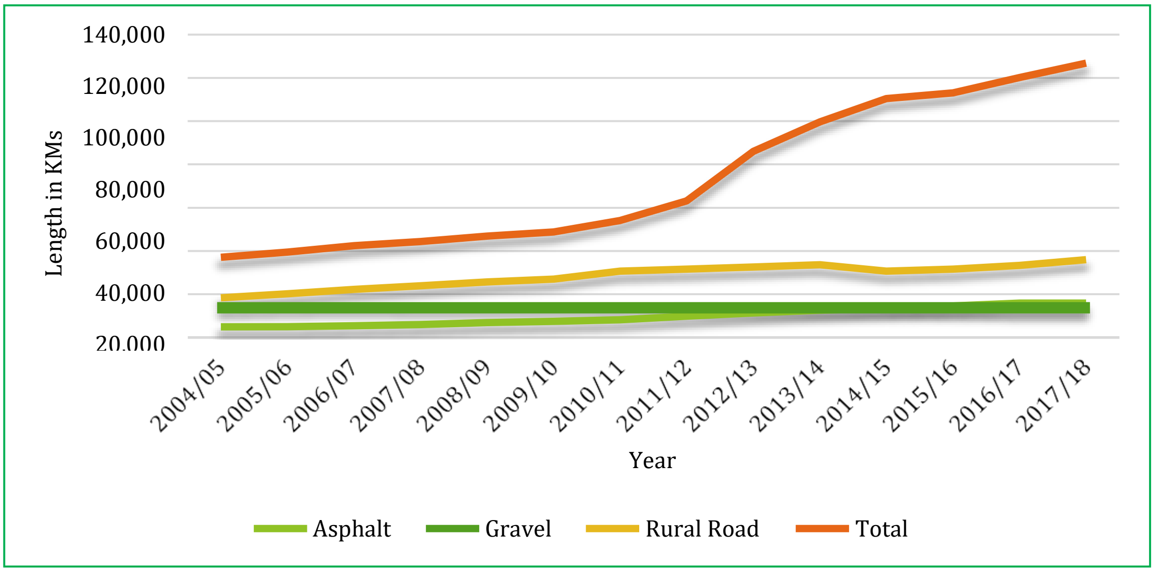

Figure 21 Length of all-Weather Roads by Type (2004-2017)

(Source: National Bank of Ethiopia,2017/18) Source: Terefi et al, 2019

The rugged terrain in Ethiopia makes road construction difficult and expensive. If we compare the length of roads to the total area of the country, we observe that it serves a small area. This is a measure of road density. Road density is the ratio of the length of the country's total road network to the country's land area and or population. One-km Road serves an area of about 66 km2. If we generously assume a distance of 10 kms on either side of a road as being accessible only about 370, 000, km2 area or 30 percent of the country is accessible. In many cases roads assume the purpose of connecting nodes or places forgetting the people and the economy in the hinterland or in between the nodes. The road density/1000 persons were 0.5 in 2004/5 that increased to 1.3 in 2018/19.

Likewise, the road density/1000 square kilometer was 33.7 in 2004/5 that improved in a way to 100.4 in 2015/16 and further to 115.2 in 2018/19. Although the road network has shown an increasing trend, the progress so far is still far below the need compared to the large land area and population of the country (Teferi et al, 2019) (Table 12)

Table 12 Road Density in Ethiopia

Year	Density /1000 Population	Density/1000Km^2
2015/16	1.15	100.4
2016/17	1.23	102.8
2017/18	1.3	109.2

Source: Terefi et al, 2019

AsshowninTable1.12above,theroaddensityhasalsoincreasedfromtimetotime.Rural roadaccessibilityis very low in Ethiopia. According to a GIS-based analysis, only 10% of Ethiopia's rural population lives within two kilometers of an all-weather road. This is only half of the benchmark level for low-income countries in Sub-Saharan Africa. Since as muchas80%ofEthiopia'spopulationlivesinruralareas,thisisahighdegree ofisolation.

The other means of transportation is railway transportation. The only rail line that connects Ethiopia to the red sea coast of Djibouti is Chemin de Fers Djibouti – Ethiopian, and that covers985kmofrail.InSeptember 2015,AddisAbabainauguratedSub-SaharanAfrica's first light rail train (LRT). The LRT, an inner-city tram, can carryupto60,000peopleperhour. The train is powered by Ethiopia's power grid, which is fueled almost exclusively by hydropower, geothermal, and wind power. Emissions reductions from the project are estimated to grow from 55,000 tons of CO_2 per year in 2015 to 170,000 tons CO_2 per year by 2030. The project is the result of an international multi-stakeholder collaboration that involved different levels of the Ethiopian government, foreign banks, and the Chinese government. It is also an important tenet of the Addis Ababa Climate Resilient Growth Economy plan to drive the transition to a green economy (Teferi et al, 2019).

Air transport is an important part of the country's transport network. Serving part of the transport network, it takes second rank after road transport in carrying passengers and cargo in the country (Worku, 2010). Ethiopia is a regional leader in air transportation. EthiopiaAirlines,oneofAfrica'sthree top international carriers, has an extensive network across the continent and a safety record up to international standards. It has been successful because it has been allowed to operate at arm's length from the government and in line with sound commercial principles. Linked to the ascendancy of the national airline, Addis Ababa Bole International Airport has become one of the three main international gateways for Sub-Saharan Africa (Worku, 2010).

1.6.5.Telecommunication

Telecommunication is one of the prime infrastructure services needed for rapid economic growth and modernization as it has a significant impact in attracting investment, creating market opportunities, enhancing competitiveness and boosting regional economic integration. Cognizant of this fact, the Ethiopian government has made huge investments in the telecom sector, focusing on improving quality of service, expansion of service coverage and enhancing institutional capacity. This policy measure has enhanced the capacity of Ethio-Telecom in terms of customer acquisition, customer satisfaction and provision of quality services to customers (National Bank of Ethiopia Annual Report, 2017/18).

below shows the trend in the number of mobile subscribers from2011/12-2018/19).

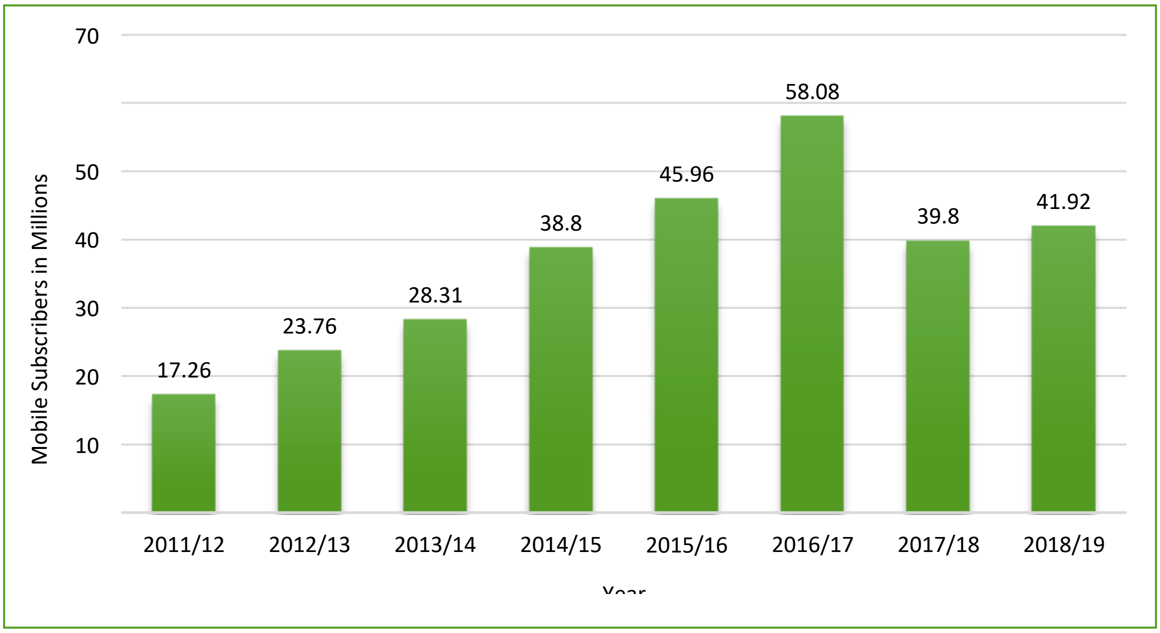

Figure 22 Trends in the number of mobile subscribers in Ethiopia (2011/12-2018/19)

Source: Statista Research Department (n.d)

As shown in **Error! Reference source not found.**above, the total number of mobile subscribers which was 17.26 million in 2011/12 has reached 58.08 million in 2016/17 showing a 70.28 per cent increase in the number of subscribers. But this figure has shown a 31.47 per cent decline and reached 39.8 million subscribers 2017/18 and again started to increase in 2018/19. The drop in mobile telecom density from 2016/17 to 2017/18 is due to eliminating inactive mobile subscribers (Statista Research Department, n.d).

As indicated in **Error! Reference source not found.**below, the country's telecommunication penetration rate (telecom density) has also increased. Tele-density is mobile plus fixed telephone subscribersper100inhabitants.Teledensityhasincreasedfrom21.4percentin2011/12 to62.6percentin 2016/17butdeclinedto40.8percentin2017/18duetotheelimination of inactive mobile services (Statista Research Department, n.d).

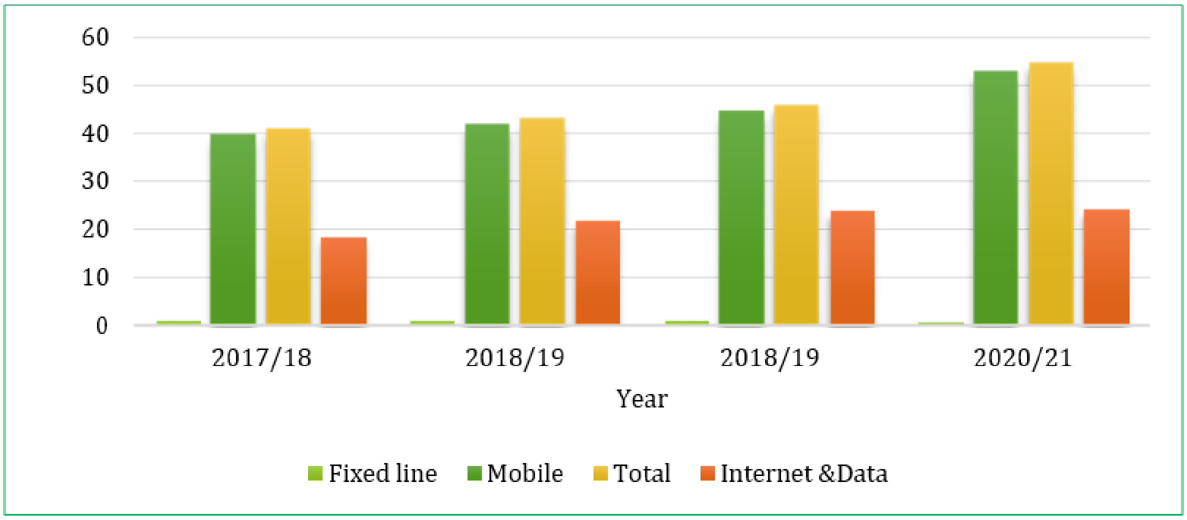

Figure 23 Telcom density/100 subscribers of Ethiopia (2017/18-2020/21). (Source: National Bank of Ethiopia Annual Report, 2020/21),

Source: Statista Research Department (n.d)

1.6.6.Tourism

Tourism is one of the largest and most important industries in the world in terms of employment creation and generation of foreign revenue. As a worldwide export category, tourism ranked fourth in 2013, after fuels, chemicals, food, and ahead of automotive products. As one of the developing countries, Ethiopia and its tourism is becoming an important sector contributing much to the social, cultural, and economic development aspects of the country (Tafesse, 2016). Though tourism development is still unsatisfactory, international tourist arrivals in Ethiopia have shown a considerable growth. Likewise, the contributions of tourism income to GDP as well as export earnings are growing in recent years (Kassahun, 2012).

The direct export earnings generated by tourism in Ethiopia are increasing, and tourism seems to be the third source of export revenue after agriculture and industry. International tourist arrivals have been on a growth trajectory since the 1990s rising from 383,000 in 2008 to 849,000 in 2018 (Figre 1.25). This has been matched by growth in the contribution of the travel and tourism sector's direct contribution to the country's GDP which in 2018 was 4.2%, and is expected to grow by 6.7% per annum reaching 6.1% of GDP by 2028 (UNWTO, n.d). Further, the industry is now an important source of employment accounting for 2.4% of total employment in 2017 representing 604,000 jobs directly and this is forecast to grow by 1.9% per annum in 2028 to 742,000 jobs (2.1% of total employment). Such performance has seen the tourism industry increasingly becoming an important economic sector in the country (UNWTO, n.d). Figure 24 shows the number of torists visted Ethiopia, revenue and per cenatge of tourisms sectors contribution to GDP for the periods 2008-2018. As shown in the two figures the number of tourists visting Ethiopia has increased from time to time. The figures also show that the revenue from the tourism sector is increasing from time to time.

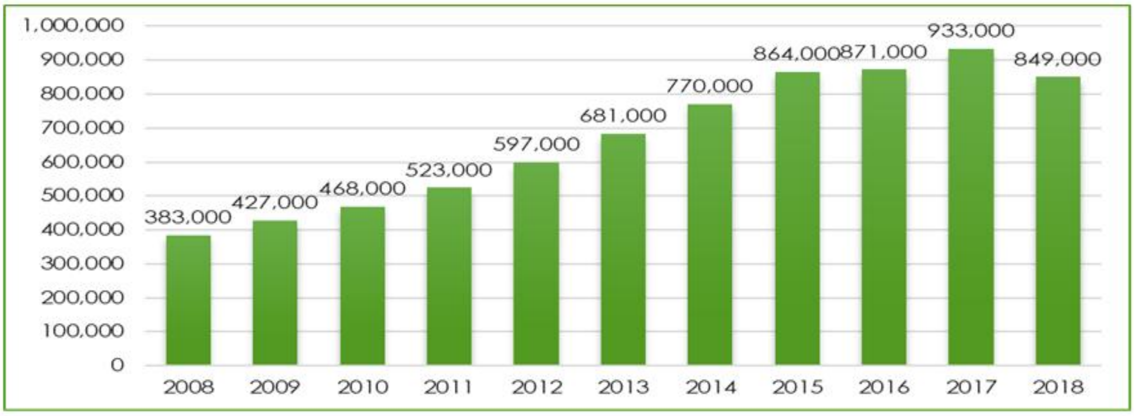

Figure 2-25: Number of tourists who visit Ethiopia (2008-2018)

Figure 25 Tourism sector's revenue and its contribution to GDP (20008-2018)

Source: UNWTO (n.d). Tourism Statistics Database

Ethiopia is endowed with unique landscape, paleontological, archaeological, historical and living cultural tourism attractions. Based on these attractions, there are diverse types of tourism in the country. The common tourism forms in the country include living culture tourism, history tourism, archaeology tourism, paleontology tourism, park tourism, geo- tourism, agro-biodiversity and coffee tourism, rural tourism, conference tourism and sport tourism.

Ethiopia has a wealth of natural and cultural resources, with some unique cultural and natural features that set it apart from other African destinations. Current international trends in world markets present opportunities to diversify the product portfolio and attract more visitors, and international markets were prioritized by the Marketing and Branding Strategy as being among the 'core' markets with high revenue potential and high affinity for leisure travel to Ethiopia, as well as among the 'steady markets' that are easier to penetrate Some of the historic attraction sites of Ethiopia include:

a) **The Obelisk of Axum:** preserves an ancient history of the era of the Axumite powerful empire having trade links as far as India and China. Visitors will enjoy the sites of these monolithic obelisks and many more wonders surrounding their history, notably the Bath of the Legendary Queen of Sheba and archaeological findings that depict the way of life of the Axumite period that reigned from pre-Christ times up until the 11th century AD.

b) **The Churches of Lalibela-** the UNESCO has named the rock-hewn churches of Lalibela as the 8th wonders of the world. Lalibela presents the site of a chain of rock carved out of 11th century churches with astonishing architectural designs and interior decorations. A historical myth narrates King Lalibela; on his own (with the help of angels) completed the construction of the churches. After his death the king has been designated as an Ethiopian saint.

c) **The Castles of Gondar-** built in the mid-17th century together with the surrounding centuries-old churches depict yet another sophisticated architectural wonders. The Castles are found in the city of Gondar, which has been the seat of government following Axum and Lalibela.

d) **The Walls of Harar-** built in the early 16th century, the walls are designated after the city of Harar. The Walls have 5 arched gates inviting to the city's popular basketworks, variety of fruits and colourfully decorated costumes of Hararie women.The city of Harar is considered as the 4th holy city of Islam.

In addition of the historic attraction sites, the natural attraction sites include:

a) **The Blue Nile Falls-** locally known as Tississat, meaning 'water that smokes' presents a spectacular waterfall with an intense gash from more than forty-five meters (150feet) peak, producing rainbows across the gorge. The area is also inhabited with fascinating wild lives and birds.

b) **Simien Mountains-** Simien mountains are home of Ethiopia's highest peak Ras Dashen with the height of 4,620 meters above sea level. With the assistance of a professional guide, the area is ideal for mountain trekking. The endemic Walia Ibex and the Gelada baboon are also found here.

c) **The Rift Valley Lakes-** Ethiopia is one of the countries that the Great Rift Valley system traverses. The Valley embraces the beautiful chains of lakes with abundant wildlife and a variety of birds. The Rift Valley comprises famous natural parks known as Abijatta-Shalla, Nechisar, Mago and Omo national parks. Each national park presents a unique feature for bird-watching, trekking and wildlife scenery.

d) **The National Parks:** Being a land of diverse geographic settings and rich natural resources, National Parks in Ethiopia, present spectacular visiting opportunities for tourists that are keen on admiring and enjoying nature.

Despite the above tourism attraction sites and its opportunity for Ethiopia's economy, the sector is greatly confronted by the following challenges:

a) Weak institutional framework and implementation capacity, skilled human resources and financing;

b) Very limited accommodating capacity of international standards for leisure tourism, with investment concentrated in main cities and business-type hotels;

c) Lack of basic and IT infrastructure present challenges for tourism businesses

d) Narrow product range offered to the market by incoming operators

e) Weak private sector associations and unplanned destination development

f) Poor visitor management in natural and heritage sites and poor tourism statistics

The direct export earnings generated by tourism in Ethiopia are increasing, and tourism seems to be the third source of export revenue after agriculture and industry. International tourist arrivals have been on a growth trajectory since the 1990s rising from 64,000 in 1990 to 681,249 in 2013. This has been matched by growth in the contribution of the travel and tourism sector's direct contribution to the country's GDP which in 2017 was 2.7%, and is expected to grow by 6.7% per annum reaching 6.1% of GDP by 2028. Further, the industry is now an important source of employment accounting for 2.4% of total employment in 2017 representing 604,000 jobs directly and this is forecast to grow by 1.9% per annum in 2028 to 742,000 jobs (2.1% of total employment). Such performance has seen the tourism industry increasingly becoming an important economic sector in the country.

1.6.7. Energy

With the growth of population and industrialization, the global energy demand is increasing at an unprecedented rate. Ethiopia is endowed with various potential sources of renewable energy. It has the potential of generating renewable energy up to 45,000

MW from hydropower, 1,350,000 MW from wind, 10,000 MW from geothermal and an average of 5.26 kWh/m2/day from solar energy. Except for the biomass fuel, most of the presented energy source is either untapped or not fully developed. For example, in terms of hydropower potential, Ethiopia is ranked second in Africa next to the Democratic Republic of Congo (DRC), but has exploited only <10% of its full potential. Table 13 below indicates the potential and exploited source of energy in Ethiopia.

Table 13 Potential and exploited source of energy in Ethiopia

S.No	Source	Unit	Potential	Exploited (%)
1	Biomass	Million metric ton/year	75	<50
2	Hydropower	MW	45,000	<10
3	Solar	kWh/m^2/day	5-6	<1
4	Wind	MW	10,000	<1
5	Geothermal	MW	10,000	<1
6	Natural gas	Billion cubic meters	113	0
7	Coal	Million tones	300	0
8	Oil shale	Million tones	253	0
9	Firewood	Million tones	1120	30
10	Agricultural waste	Million tones	15-20	30

Source: Mondal et al (2017)

Ethiopia, is heavily reliant on biomass-based energy by consumers for household purposes(Figure 26 Potential and exploited source of energy in Ethiopia

). The largest energy supply comes from waste and biomass covering up to 92.2% share of the total primary energy supply followed by oil (5.7%) and hydropower (1.6%). Coal and Geothermal/Solar/Wind account for 0.4 % and 0.1 % of household's energy consumption. According to Ethiopia's country report in 2019, only about 45% of the country's population has access to electricity. From this, urban population has 97% access to electricity, while in rural areas electricity access remains extremely low at about 31% (Mondal et al,2017).

Ethiopia is one of the countries in Africa in which energy resources are underexploited, as evident from the past, significant energy demands are still met from traditional resources.Currentlythefinalenergy consumption of the country is around 40,000 GWh, in which about 92% are consumed by domestic appliances, 4% by the transport sector and 3% by industry. However, energy supply thereby is covered by bio-energy which accounts for about 90% of final energy consumption. While the transport sector is predominantly run by imported petroleum; which accounts for about 4.5% and modern energy contributes only about 6% of the overall energy consumption (Mondal et al., 2017).

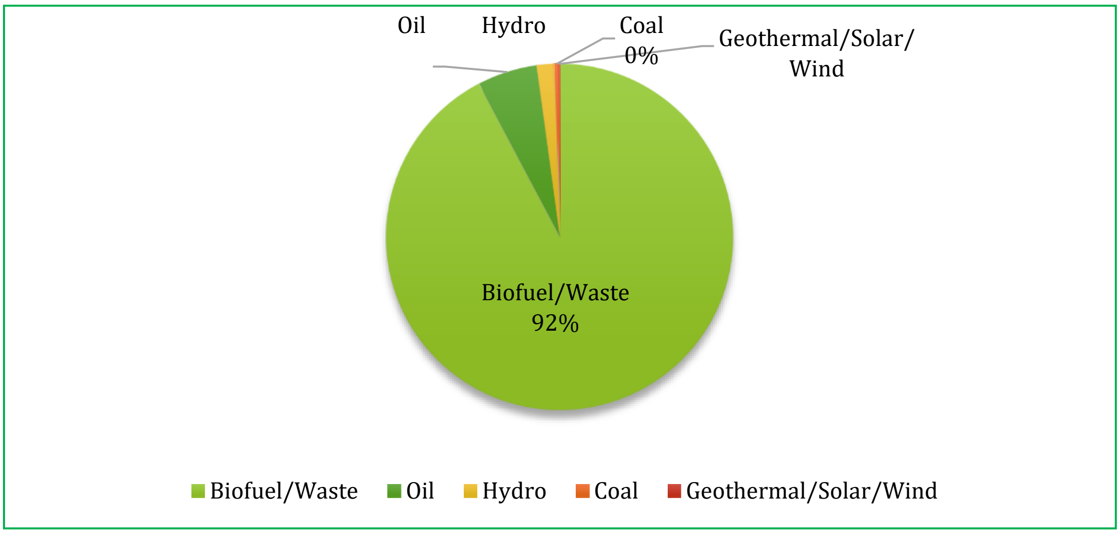

Figure 26 Potential and exploited source of energy in Ethiopia

Source: Mondal et al (2017)

Country depends heavily on biomass as an energy source, which accounted for about 45.8 out of 49.9 million tonnes of oil equivalent (Mtoe) of total primary energy supply in 2015. Figure 27 Share of total primary energy supply in Ethiopia as of 2015below shows the sources of energy for lighting purposes. As shown in the Figure, collecting firewood is the dominant source of firewood accounting for 73%. This is followed by purchase of firewood accounting for about 13%. Whether collected or purchased, firewood accounts for about 86% of the source of firewood. Charcoal and crop residues/leaves are also important sources of cooking accounting for about 5% and 4% respectively (Mondal et al., 2017).

When we look at the sources of lighting, the majority of households in Ethiopia use electrical battery (Fig.1.26). About 24% of the households also use kerosene as a source of light. Shared and private electricity also account for about 18% and 10% respectively.

As discussed above, Ethiopia is estimated to have a hydropower production potential of 45,000 MW, a geothermal potential of 10,000 MW and 1.3 million MW potential from wind farms. The country's generating capacity; however, is largely based on hydropower reservoirs as nine of its major rivers are suitable for hydroelectric power generation. Considering the increasing power demand and capacity shortfall in the system and with a view to have a better power generation mix, the country has ventured to diversify its production of renewable energy towards wind and geothermal sources. Consequently, with the Adama II wind farm which has a generating capacity of 153 MW combined with Adama I (51MW) and Ashegoda (120 MW), the total energy production from wind has reached 324 MW. In addition, the construction of Aysha 300 MW wind power project is underway. Ethiopia is also identified as having a huge solar energy potential due to its geographical location near the equator. In its bid to become a major power exporter and green economy in East Africa, the country is building several geothermal power plants. The amount of electric power generated in 2018/19 was about 13.2 billion KWH. About 95.6% of the electric power was generated through hydropower, 4.2 % from wind and 0.31 % from biomass sources (CSA, 2018).

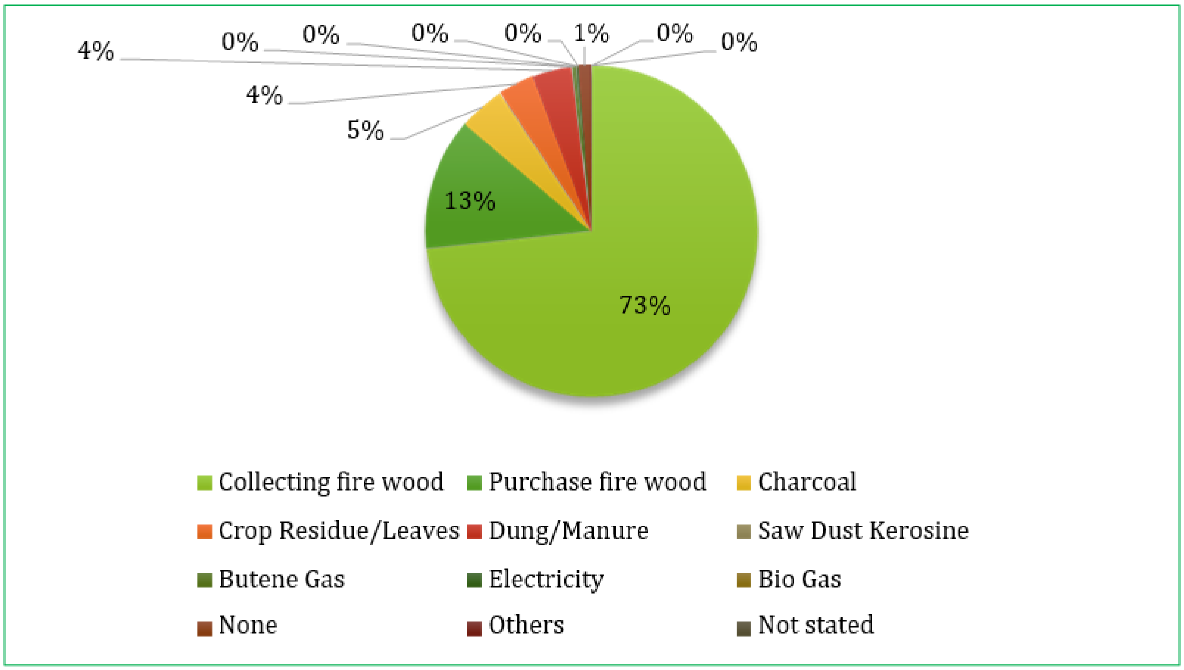

Figure 27 Share of total primary energy supply in Ethiopia as of 2015

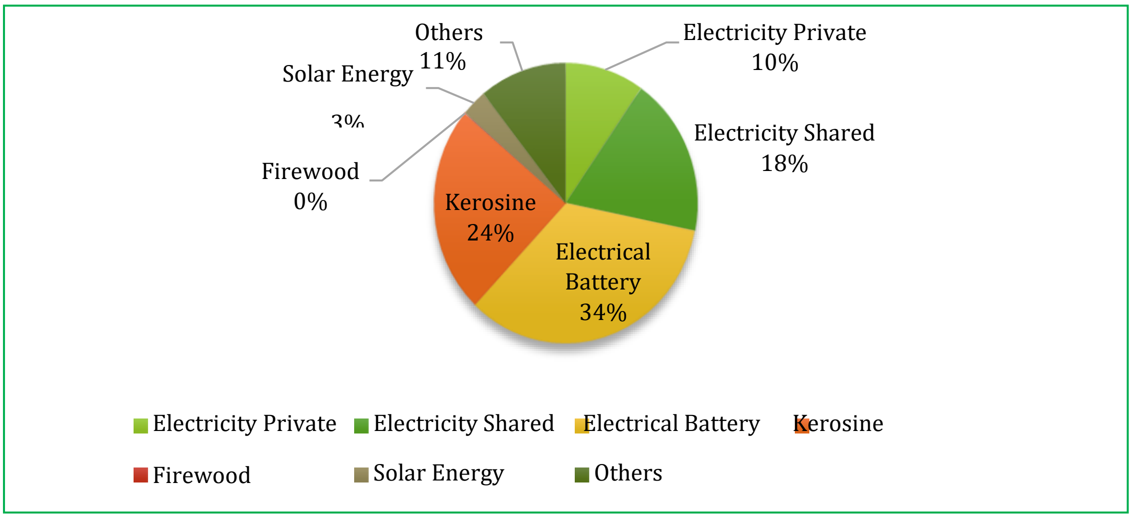

Figure 28 Household's Source of energy for cooking.

Source: 2016 welfare and monitoring survey

1.6.8.Mining

Mining is important to the economy of Ethiopia. Currently, mining contributes to only 1.5% of GDP. The Geology of Ethiopia and the Horn, mineral occurrences are associated with the geologic process. The oldest (Precambrian) rocks and the sedimentary (Mesozoic) rocks host most of the economic metallic and nonmetallic mineral deposits in Ethiopia (Teferi et al, 2019).

So far, the developed large scale gold mine in Ethiopia is the Lege-dembi gold mine, located in the southern greenstone belt region. It is operated by private company with estimated reserve of 82 tons and an average annual production of 3.6 tons of gold. There is also small-scale open pit mine of columbo-tantalite at Kenticha in the Adola belt. The deposit is both a weathered crust ore (the top 60 meters) with proven reserve of 2400 tons of tantalum pentaoxide and 2300 tons of niobium pentaoxide, and primary ore with proved reserve of 2393 ton Ta2O5 and 2362.5-ton Nb2O5. The Mine has been operating since 1990 with a pilot plant producing about 20 tons per year. At present it is producing over 190 tons of tantalite concentrate of tantalite columbite ore per annum. Tantalum is used in making all electronic devices such as mobile phones, cameras, computers and so forth and is thus highly demanded. Ethiopia presently supplies close to ten percent of the World production of tantalum and has a good potential for a considerable expansion of the percentage (Ministry of Mines & Energy, 2015).

Secondary enriched (placer) gold has been mined traditionally (artisinaly) for years back to biblical times. Formalization of the artisanal miners has been strengthened since the early 2000's that about 1000 Kg of gold is purchased from the local miners and dealers by the National Bank of Ethiopia that in turn increases the generation of foreign currency. Soda ash is being mined at Lake Abiyata in the Rift Valley about 200 kilometers south of Addis Ababa. The reserve at Lake Abiyata and the surrounding lakes exceeds 460 million tons of sodium carbonate at salt concentration ranging from 1.1 to 1.9%. The plant is producing about 5,000 tons soda ash per year at semi-industrial scale. The consumers of the soda ash are local caustic soda factory, soap and detergent manufacturers (Ministry of Mines & Energy, 2015).

Kaolin, quartz and feldspar are also being mined from the Adola belt in southern Ethiopia by government enterprise. The consumers of the products are the Awash-Melkasa Aluminium Sulphate and Sulfuric Acid Factory and the Tabor Ceramics Factory. Silica sand has been mined and utilized by local industries. The cement factories of the country are using high quality limestone, clay, gypsum and pumice as a raw material for cement production. There is also large input of construction minerals such as sand, gravel, scoria, crushed stones, aggregates, pumice, scoria, etc to the construction industry (including buildings, roads, dams, bridges etc.). The gas fields are located in the south-eastern part of the country at Calub, Hilala and Genale gas fields in the Ogaden Basin. The gas resources potential of these fields has been assessed as 4.6 Trillion Cubic Feet (TCF). Other mineral products including platinum from laterite, gemstones (opal and other precious stones) and decorative and construction materials are also produced by licensed foreign and local mining companies in the southern, western, central and northern regions of the country (Ministry of Mines & Energy, 2005; 2015).

The mining laws of Ethiopia have been issued in 1993 and amended recently, to attract private sector investment compared to other developing countries mining codes. The 1994 mining regulation was also issued to make all licensing and administration procedures as transparent as possible. Encouraging foreign and local mineral development investments have been shown since late 1990's. The total investment amount registered by the private sector to date is about 1.1 Billion US Dollars where by 95% percent of it is direct foreign investment for the development of precious and industrial minerals.The mining stakes in Ethiopia are held by the Ethiopian Mineral Development Share Company, a Government organization (EMDSC) established in 2000 is engaged in all mining activities in the country; the Ezana Mining Development, functioning since 1993, a privately owned Ethiopian enterprise in consulting in all aspects related to mining including all types of explorations; the Midrock Gold, a subsidiary of Midrock Gold Group, in operation at Shakisso town in southern Ethiopia, involved in gold mining (production of 3500 kg of gold per year extracting 50,000 tons of rock per month); and the National Mining Corporation (set up in 1993), a private company involved in all facets of mineral and petroleum product production including by products.Potash mining has generated lot of interest in recent years. Allana Potash, a Canadian mining company is poised to start mining for potash in the Afar Regional State while the Indian Sainik Potash has been working in the Dallol depression (Ministry of Mines & Energy, 2005).

Prospecting for iron, gold and base metals is also in progress in many regions of the country. More and more gold mines are being located, such as in the Afar region and in the Konso Zone in southwestern Ethiopia. Presently a number of junior exploration and world class mining companies are operating in Ethiopia for different mineral commodities. Apart from these there are wide ranges of future investment opportunities found in Ethiopia that hope to be of mutual benefit to the investors and the speedy socioeconomic development of the country.It is inevitable that extraction of minerals from the earth leads to disturb the environment. When disturbing the environment there must be careful and systemic protection of the whole system of environment that assures sustainable use of the current resource and or ecosystem and that bring about either less or almost none destruction or pollution of the environment (Ministry of Mines & Energy, 2005; 2015).

The mining legislation of Ethiopia, which came in to effect in 1993 has provision that requires as compulsory criteria to study, submit and get approval of Environmental Impact Assessment from the respective Authority in order to develop large scale mining project. The common environmental issues in Ethiopia to be considered in development of the medium to large scale mining projects are the surface and ground water system, the physical land management (soil, rock stability, deforestation grass land, farm land, etc), spillage of strange chemicals/metals, air, noise, dust, aesthetic values of the area, cultural and tourist heritages, the communities as well as all other lives surround the mine proximity. In principle the licensees shall ensure the financial mobilization of the environmental management and mine closure plan. Therefore, sinking fund is required to be pledged while the mining activity is going on and management plan shall be implemented throughout the life of the mine.

1.7. Natural Resources, Biodiversity and Ecosystems

1.7.1. Geology and Soils

The basement upon which all the younger formations were deposited contains the oldest rocks in the country, which are the Precambrian rocks (Fig. 1.29). The Precambrian contains a wide variety of sedimentary, volcanic and intrusive rocks which have been metamorphosed to varying degrees. The basement in the south and west of the country, where granitic rocks and gneisses predominate, has been more strongly metamorphosed than the Precambrian sequences in the north. Though in many cases strongly folded and foliated, the rocks in the north, which include the youngest formations yet known in the Precambrian, have generally undergone only weak metamorphism, reflecting the relatively low temperatures to which they have been subjected since their deposition. Much of the surface of Ethiopia is covered by Cenozoic volcanic flows, shield volcanoes, and plugs. The extensive volcanic activity is directly related to the underlying long-term plume, tension and extension; and creation of the Red Sea and Gulf of Aden rifts extending into the East African Rift System via the Afar and Main Ethiopian Rift (MER).

The surface geology of Ethiopia is characterized by different formations along the rift valley and the outcropping highlands. In the northeast-southwest-Rift valley is lined with the Tertiary and Quaternary volcanic rocks. In the eastern half of the highlands and in the Ogaden plains, the Jurassic, Cretaceous, and Tertiary sedimentary rocks are dominant. The sediment outcrops explain the Ogaden plain and defines a potential hydrocarbon bearer. Whereas, the western half of the highlands and plains are dominated by Cenozoic volcanic cover but with Jurassic and Cretaceous sedimentary rocks exposed along the western and northern limits, revealing the Blue Nile Basin beneath and the Mekele outlier to the north (Abbate et al., 2015).

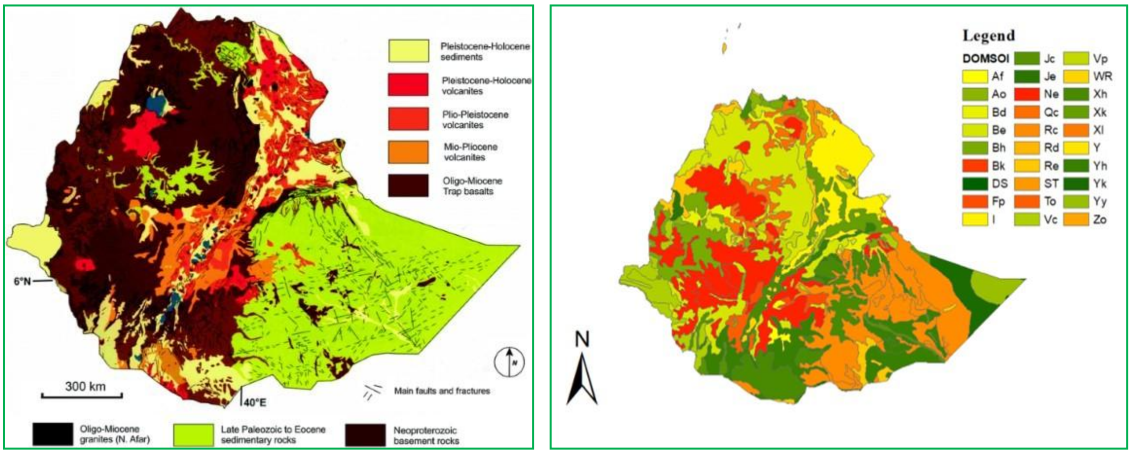

Figure 29 The major geological formations (left) and Soil types (right) of Ethiopia

1.7.2.Soils

According to the FAO Soil classification of Ethiopia (1998), there are about 18 soil groups Figure 28. However, estimates show that about 80 % of the country is covered by nine major soil types. Some of these soil types and their percentage area coverage are Cambisols (21 %), Regosols (20 %), Nitosols (16 %), Yermosols (13 %), Xerosols (11 %), Vertisols(5%),andLithosols(7%),togetheraccountingfor93%ofthe area covered by soil (FAO, 1998). Various general clusters of similar soil types can be distinguished, such as Nitisols in the southern part of the Western Ethiopian Highlands; and Luvisols and Leptosols, with isolated occurrences of Cambisols, in the northern part of the western Ethiopian Highlands. The extreme variability of the spatial extent of Ethiopian soils is caused by the wide range of topographic and climatic factors, the diversity of parent material, and the variability of the uses to which has been put. The complexes of soil forming factors have primarily influenced the distribution of the soil types. It is worth notingthattheinformation on soil fertility status is inadequate. However, research has shown that the potassium, nitrogen, cation exchange capacity (CEC) and organic matter content of most mountain soils is high, while there is a general deficiency in phosphorous content.

1.7.3.Water Resources

Ethiopia has abundant water resources, but they are subject to high hydrological variability.Besides, studiesindicatethatthecountryhasanannualsurfacerun-offofclose to 122 billion m^3 of water excluding ground water. The hydrology of Ethiopia formsa foothold for the water resources in the Horn of Africa, including Sudan and Egypt.

Ethiopia manages its surface water through 12 basins (Figure 28), which are part of four transboundary basins:theNile,RiftValley,Shabelle-Juba,andNorthEastCoast. Besides, characteristicsofEthiopia'smain basins are summarized in table 3 and 4. Conversely, the water resources in Ethiopia are unevenly distributed, both spatially and temporally. For instance, the western Abay (Blue Nile), Baro-Akobo, Mereb, and Setit-Tekeze/Atbara Basins are part of the Nile Basin, which generates 70% of the country's renewablesurface water, mostly through the Abay Basin.

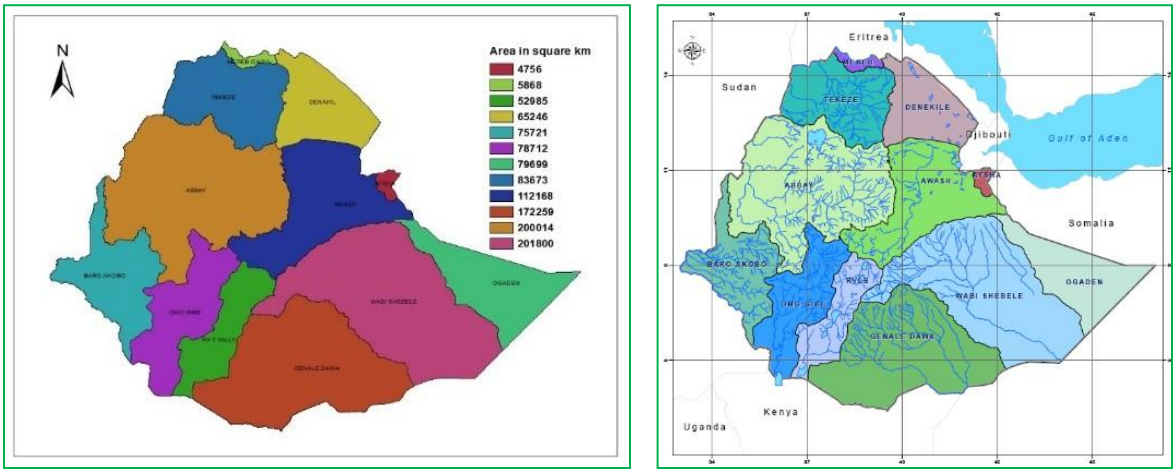

Figure 30 basins and Water Bodies of Ethiopia (Area in square km)

Collectively, these basins provide 86% of the Nile's annual flow. The Afar-Denakil, Awash, Omo-Gibe, and Rift Valley Basins in central and northeastern Africa account for more than 20% of surface water resources and are part of the Rift Valley Basin, which spans much of East Africa. Water supply is concentrated in the southern Omo-Gibe and Rift Valley Basins. The Awash Basin accounts for 4% of the national supply, while water availability in the northernmost Afar-Denakil Basin is negligible. The Awash Basin has limited supply and high demand, with low average annual precipitation. The eastern Wabi-Shebelle and Genale-Dawa Basins are part of the Shebelle-Juba Basin and contain eight percent of Ethiopia's surface water. The Ogaden and Aysha basins are included in the North East Coast Basin, but they are considered dry basins with rivers that flow only after rainfall. The surface water resource potential is impressive, but littledeveloped (Figure 29)

Table 14 Characteristics of the Basins in Ethiopia

No.	Basin Name	Type	Source	Area (km^2)	:tion of Flow	Terminal
1	Aysha	D	No flow	2,223	NF	Internal
2	Mereb	R	Adigirat HL	5,900	West (Nile)	Swamp inSudan
3	Rift Valley Lakes	L	Arsi and Central HL	52,000	South	Chew Bahir
4	Baro- Akobo	R	Western Highland	75,912	West (Nile)	Mediterranean Sea
5	Omo- Ghibe	R	Central, Western HL	79,000	South	Rudolph Lake (Internal)
6	Wabi shebelle	R	Bale Highland	202,220	East	Indian Ocean
7	Abbay	R	West, Southwest HL	199,912	West (Nile)	Mediterranean Sea
8	Genale Dawa	R	Bale Highland	172,259	East	Indian Ocean
9	Awash	R	Central highland	110,000	North-east	Terminal Lakes (Internal)
10	Tekeze	R	North Wollo Highland	82,350	West (Nile)	Mediterranean Sea
11	Denakil	D	North Wollo Highland	64,380	NF	Internal
12	Ogaden	D	No flow	77,120	NF	Internal

Ethiopia has about 30 Lakes distributed all over the country, but more concentrated in the rift valley. Except for some lakes which are deep and > 150 m, such as Lakes Shala (266 m), Babogaya (65 m), and some crater lakes (Zengena Kibeb in Awi zone) and Lake Wonchi, most of the other lakes are shallow (about 20 – 50 m). But the largest lakes, such as Tana and Zwai are shallow and < 10 m deep, although in previous citations, they were reported to be > 10 m ( ). Lake Tana (Abay Basin) is the largest and is a critical water source for the Nile River. There are also numerous large lakes in the Rift Valley Basin although most are saline. Conversely, groundwater supplies 90% of domestic, municipal, and industrial needs. Groundwater use in irrigation is low. Studies on groundwater sustainability and abstractions are generally limited. Ethiopia also has 1.8 million hectares of wetlands and floodplains, which are concentrated in the Nile and Rift Valley Basins.

Table 15 Area and annual runoff by river basin

Major drainage system	River basin	Area (ha)	As % of total area	Annual runoff (million m³/yr)	of total runoff
Nile Basin		36 881 200	32.4	84 550	69
	Abbay (Blue Nile)	19 981 200	17.6	52 600 42.9	42.9
	Baro-Akobo	7 410 000	6.5	23 600	19.3
	Setit- Tekeze/Atbara	8 900 000	7.8	7 630	6.2
	Mereb	570 000	0.5	260	0.6
Rift Valley		3176400	27.9	29.020	23.7
	Awash	1127000	9.9	4600	3.7
	Afar-Denakil	740000	6.5	860	0.7
	Omo-Gibe	782000	6.9	17960	14.7
	Central Lake	527400	4.6	5600	4.6
Shebelli- Juba		37 126	400	32.7	7.3
	Wabi-Shebelle	20 021 400	17.6	3 150	2.6
	Genale-Dawa	17 105 000	15.1	5 800	4.7
North-East Coast		7 930 000	7	0	0
	Ogaden	7 710 000	6.8	0	0
	Golf of Aden/Aysha	220 000	0.2	0	0
Total		110 430000	100	122000	100

(Source: FAO. 2016. AQUASTAT Country Profile –Ethiopia.)

The Ethiopian wetlands are distributed in different parts of the country, in almost all ecological and altitudinal ranges covering approximately 2% of its total surface area. The Dallol depression which is located at about 110m below sea level flourishes with wetlands such as Lake Afdera (salty lake). Swamps, marshes, lakes and riverine ecosystems are also distributed in central highlands, rift valley areas and mainly in the southwest borders of the country. The country lacks a wetland database as comprehensive wetland study has not been carried out yet.

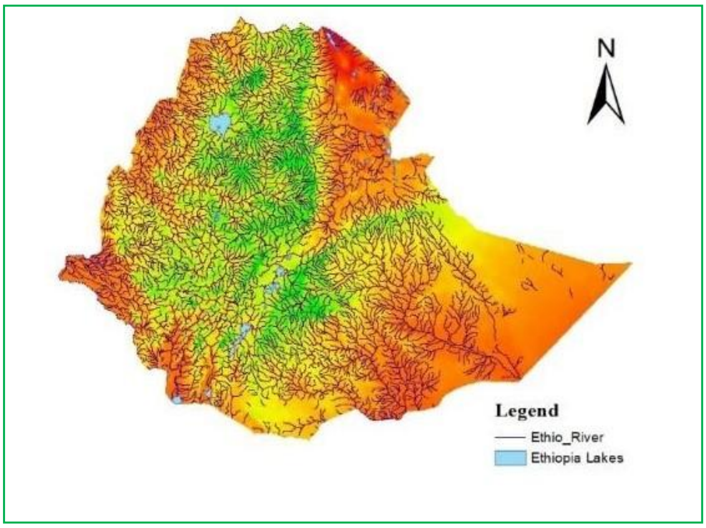

Figure 31 Lakes of Ethiopia (blue-colored)

Besides, during 2019/20, the proportion of people having access to potable water supply improved to 79.3 % (82.7 % rural and 66.5 % urban population); relative to 75.9 % (78.7 % rural and 65.5 % urban people) a year earlier. The GTP II had set potable water supply coverage at national level at 83 percent for the year which was 3.7 % higher than the actual performance. In terms of regional sates, Amhara registered 90.3 % in people accessibility to potable water followed by Dire Dawa (84.8%), Somali (83.3%), Harari (73.9 %), Gambella (73.7 %), Oromia (71.2 %), Afar (67.5 %), Benshangul Gumuz (64 %), Addis Ababa (63.9 percent), SNNPR (63.6 %) and Tigray (62.9 %) (Table 1.18).

Table 16 Percentage of People with Access to Potable Water by Region

2019/20			
Regions	Rural	Urban	Total
	A	B	C
Tigray	57.51	72.46	61.76
Afar	57.13	63.42	58.41
Amhara	69.11	67.52	68.81
Oromia	55.4	67.1	56.9
SNNPR	45.29	52.54	46.55
Somali	26.58	35.84	27.95
B.Gumuz	64.1	58.07	62.72
Gambella	72.05	80.8	75.17
Harari	94	42.54	65
D. Dawa	67.96	98.43	87.31
AA		63.72	63.72
Total	54.87	63.2	56.54

(Source: Ministry of Water and Energy)

The country has an estimated hydro-power potential of 45,000 MW, geothermal of 10,000 MW and 1.3 million MW from wind farm. Currently, the country's generating capacity is largely based on hydropower reservoirs as nine of its major rivers are suitable for hydroelectric power generation. The total amount of electric power generated during 2019/20 was 15.2 billion KWH, showing 9.8 percent year-on-year growth. Of the total production 94.8 percent of the electric power was derived from hydropower, 4 percent from wind and 1.2 percent from biomass sources. The hydro power energy production got momentum as the total electric energy generated increased to 14.4 billion KWH from 13.2 billion KWH depicting 9 percent annual expansion, while energy production from wind and biomass rose by 4.2 and 314.7 percent respectively over last year (Table 17)

Table 17 Electric Power Generation in ICS and SCS

	Source	8/19 [A]	Share (In %)	9/20 [B]	Share (In %)	Percentage Change[B/A]
ICS	Hydro Power	13211643.83	95.5	14403774.7	94.8	1.09
	Thermal Power	-	-	-	-	-
	Geothermal	-	-	-	-	-
	Wind	584735.35	4.2	609026.6	4	1.04
	Biomass	43254.5	0.3	179372.6	1.2	4.15
Sub Total		13839633.7	100	15192173.8	100	1.10
SCS	Hydro Power	-	-	-	-	-
	Thermal Power	-	-	-	-	-
Sub Total		-	-	-	-	-
Total	Hydro Power	13211643.83	95.5	14403774.7	94.8	1.09
	Thermal Power	-	0	-	-	-
	Geothermal	-	0	-	-	-
	Wind	584735.35	4.2	609026.6	4	1.04
	Biomass	43254.5	0	179372.6	1.2	4.15
Grand Total		13839633.7	100	15192173.8	100	1.09

(Source: Ministry of Water and Energy

1.7.4.Vegetation Types and Forest Resources

Because the diverse topography and the wide altitudinal variation, Ethiopia is endowed with a variety of vegetation types encompassing the grasslands to the high mountain forest vegetation types distributed across the landscapes (from Dalol depression of 126 mbsl to the tip of the Ras Dashe mountain at 4620 masl). As area result, there are twelve major vegetation types identified in the country (Friis et al. 2010). These are described in **Error! Reference source not found.** and the distribution is shown in .

Table 18 Major vegetation types of Ethiopia

No	Vegetation type	Altitude range (m.a.s.l)
1	Desert and Semi-desert Shrubland (DSS)	includes areas with altitude < 400 m
2	*Acacia-Commiphora* woodland and bushland	In areas between 400 and 1800 m
3	Wooded grassland of the western Gambela region (WGG)	In areas between 450 and 600 m
4	*Combretum-Terminalia* woodland and wooded grassland (CTW)	In areas between 400 and 1800 m
5	Dry evergreen Afro-Montane Forest and Grassland complex (DAF)	In areas between 1800 and 3000 m
6	Moist Evergreen Afro-Montane Forest (MAF)	In areas between 1800 and 3000 m
7	Transitional Rain Forest (TRF)	In areas between 500 and 1500 m;
8	8. Ericaceous Belt (EB)	In areas between 3000 and 3200 m
9	9. Afro-alpine vegetation(AA)	is found in areas at altitudes > 3200 m;
10	10. Riverine Vegetation (RV)	Along rivers below 1800 m
11	11.Freshwater lakes–lakeshores, marshes, swamps and floodplain vegetation (FLV)	Global Wetlands Database (GLWD); fresh water Lakes shorelines (Tana)
12	12.Salt–water lakes, lakeshores, salt marshes and pan vegetation(SLV)	GLWD; Brakish Lakes shorelines

The forests are found in the Dry evergreen Afromontane Forest and Grassland complex (DAF); in the Moist Evergreen Afromontane Forest (MAF); the Riverine Forest (RF) and Transitional Rain Forest (TRF). Whereas the woodlands are found mainly in the Acacia- Commiphora woodland and bushland; Combretum-Terminalia woodland and wooded grassland (CTW) and the Wooded Grassland of the western Gambela region (WGG).

The total forest resources (as per the national definition of forests) are estimated to be about 17.4 million hectares, covering about 15.7% of the total land are of the country. Given the vast degraded lands that can be converted to forests, the foresty sectoris identified as one of the potential sectors to develop and contribute to the country's economic growth.

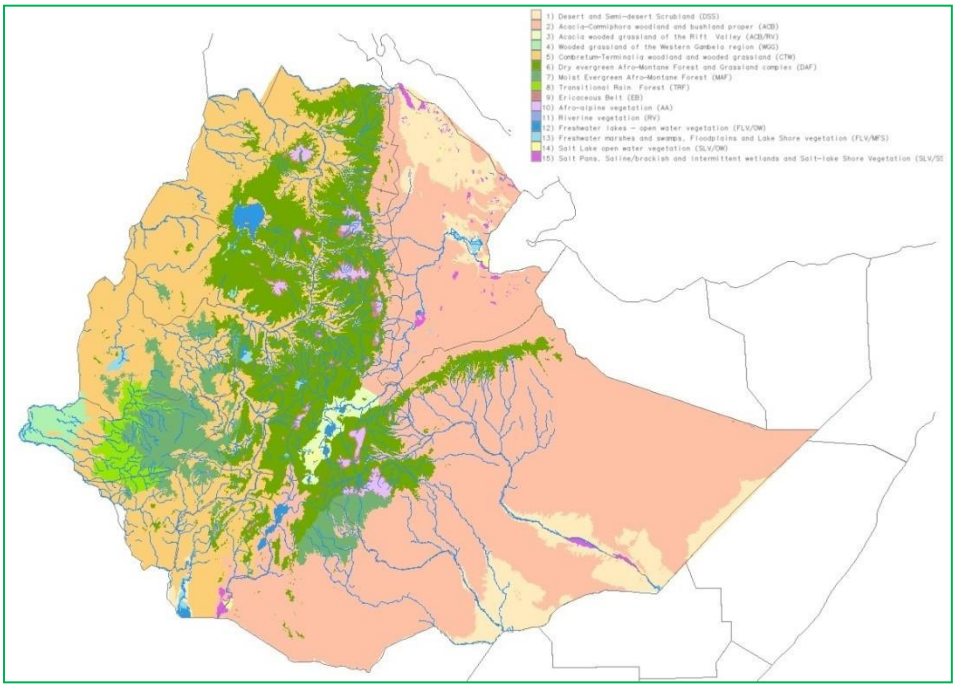

Figure 32 Vegetation types of Ethiopia

(Source: Friis et al. 2010)

The Country has diverse topography with an enormous altitudinal variation ranging from 126 meters below sea level at Denakil Depression to 4,620 meters above sea level at Mount Ras Dashen. This, in turn, has resulted in wide differences in rainfall, humidity, temperature and associated variables that paved the way for formation of diverse ecological systems: Afroalpine and Sub-afroalpine, Montane Grassland, Dry Evergreen Montane Forest and Evergreen Scrub, Moist Montane Forest, Acacia-Commiphora Woodland, Combretum-Terminalia Woodland, Lowland Tropical Forest, Desert and Semi-desert Scrubland, Wetland, and Aquatic Ecosystems (according to the Ethiopian National Biodiversity Strategy and Action Plan 2015-2020 document). Furthermore, the natural settings as well as the cultural diversity are recognized to have contributed to the Country's enormous diversity, mainly through varied traditional farming practices that enhanced agro-biodiversity.

1.7.5.Protected areas and wildlife resources

Protected areas generally include National Parks, controlled hunting areas, sanctuaries, wildlife reserves, biosphere reserves, forest priority areas, lakes and community conservation areas. Since the early 1960s, Ethiopia has designated many protected areas that include 27 National parks, 5 biosphere reserves, 2 wildlife sanctuaries, 6 wildlife reservs, 8 community conservation areas, and 25 controlled hunting areas and 37 National Forest Priority Areas that are considered as protected areas (**Error! Reference source not found.**) (MEFCC 2018). The protected areas in total cover about 14% of the country. The majority of the PAs are found in the forest and woodland ecosystems. The afroalpine national parks (Semien and Bale mountains), are habitate for the large endemic mammals such as Walia Ibex, Mountain Nyala, Starck's Hare, Ethiopian Wolf and Gelada Baboon. The Giant Mole Rat is also a characteristic species to this ecosystem and the characteristic birds include Chough, Ruddy Sheld Duck, Spot-breasted Plover, Blue winged Goose, Wattled Crane, Lammergeyer, and Golden Eagle. The common typesofwildlifeintheprotectedareasofthesemi-aridzonesinthelowlandsplainsand inthethe rift valley include reticulated giraffe, Grant's gazelle, Oryx, Burchell's zebra, waterbuck, elephant, lion, duiker,greaterkudu,lesserkuduandbuffalo.TheEthiopian Rift system is in the arid/semi-arid zone.

Table 19 Partial list of the National Parks with the key species of protection

Protected Area	ıimal/plant species	Major ecosystem/ vegetation type	Year established	Area (km²)
Awash National Park	Beisa Oryx, Lesser Kudu, Waterbuck,	ACB	1958	756
Simein Mountains National Park	Walia Ibex, Ethiopian Wolf, Gelada Baboon	DAF, CTW	1959	412
Alitash National Park	Elephant	CTW	1997	2,666
Bale Mountains National Park	Nyala, Minelik's Bushbuck, Ethiopian Wolf	MAF/DAF	1962	2,200
Abijata-Shalla Lakes National Park	Pelican, Flamingoes	ACB	1963	887
Omo National Park	Common Eland, Buffalo, Elephant	CTW	1959	3,566
Nechsar National Park	Zebra, Greaterand LesserKudu	ACB	1966	514
Mago National Park	Buffalo, Zebra, Hippopotamus	CTW	1974	1,942
Chebera Churchura National Park	Elephant, Lion	MAF, CTW,TRF	1997	1,190

1.7.6.Biodiversity

Ethiopia is one of the mega-diverse countries in the world and a large part of the country covers a large proportion of the two major biodiversity hotspots among the 34 in the world. These are the Eastern Afromontane and the Horn of Africa hotspots. Ethiopia is also the centers of diversity and origin of several cultivated crops including *Coffee arabica*.

Ethiopia is the only country that has standing populations of wild *Coffee arabica* in the mountain rainforests. Ethiopia is also recognized to be a center of endemism for several species). There are an estimated number of over 6000 species of higher plants and 10% of which are endemic. Besides, there are 284 species of wild mammals and 861 species of birds. Although complete data are scanty, there are several species of reptiles, fish, amphibians and arthropods (Table 1.22). Good number of them are endemic to Ethiopia. Ethiopia is a center of origin for cultivated crops such as coffee, tef and enset; center of diversity for durum wheat, barley and sorghum.

Table 20 Species and Endemics in Ethiopia by Group (Source: National report on the implementation of NBSAP

Group	Number ofSpecies	Number of Endemics	% of Endemics
Mammals	320	31	11
Birds	861	28	3
Reptiles	201	9	4
Amphibians	63	24	38
Freshwater fish	168-183	37-57	22-31
Butterflies	324	7	2
Plants	6,044	~1,150	~19

(EBI: 2015-2020)

Ethiopia has well established institutions for biodiversity conservation and has made significant progress in conserving its biodiversity resources. In both the ex-situ and in situ systems, a total of about 12,000 new accessions of plants have been collected and conserved since 2014. Besides, 381 microbial species have been conserved in the ex-situ in the national gene bank. Several field gene banks have been established for conserving coffee, medicinal plants and forest plant species. Ranches and cryo-conserving of frozen semen doses are used to conserve indigenous cattle breeds. Community gene banks and *in-situ* conservation sites are used to conserve enset, durum wheat, tef, coffee, medicinal plants and forest plant species.

One of the most critical threats to the biodiversity resources of Ethiopia is habitat destruction. Other factors include unsustainable utilization, invasive species, replacement of local varieties and breeds, climate change and pollution. Besides, population pressure, poverty, weak local capacity and lack of awareness are some indirect causes of biodiversity loss in the country. Because of these threats and pressure on ecosystems, farmers' varieties and indigenous population of animal breeds are declining. From the past records, a total of 103 tree and shrub species, 31 birds, one reptile, nine amphibians, two fish and 14 other invertebrate species are threatened. Concerted efforts and various measures have been taken by the Ethiopian biodiversity institute to decrease the rate of habitat destruction/conversion due to agricultural expansion (

). The interventions include alternative jobs creation for local communities, adoption of improved technologies and innovations for increased productivity of smallholder farmers and pastoralists.

Table 21 Some of the measures taken to reduce habitat conversion

No	Alternative jobs created/services delivered to local communities		Quantity (No.)	Sectors where jobs were created/services delivered
1	Jobs created	Permanent	1,500,000	Metal, Leather, Garment, Chemical, Construction and Protected areas
		Temporary	84,410	
2	People benefited through income generation		720,000	Forestry sector
3	Improved stoves distributed 10,000,505 Energy sector		10,000,505	Energy sector
4	Solar site established		49	Water sector
5	Wind energy water installed for supply		4	Water sector
6	Biogas plantsestablished		12,387	Energy sector
7	Solar home systems disseminated		107,633	Energy sector

(EBI, 2015-2020)

1.7.7.Major ecosystems and their status

In the recent national assessment and re-classification of the eco-regions, Ethiopia has five district types of Ecosystems. These are Mountain ecosystems, Forest and woodland ecosystems, Aquatic and wetlands ecosystems, Rangeland ecosystems and Agro- ecosystem. The estimated area coverage of the five ecosystems is shown in Table 1.24 below. While the rangeland ecosystem covers about 69 % of the total area of the country, the forest and woodland ecosystem and the agro-ecosystems cover 15-27 % and 9.2-22 % of the country, respectively

The trend and status of each of the ecosystems has been assessed and findings suggest that there has been a continuous decline in the extent of area and degradation of the habitat quality. The status of each of the major ecosystems are described below.

Table 22 Estimated extent and coverage of the five major ecosystems of Ethiopia

system Types	Area (in km^2)	Area (% of country's area)	Descriptive remarks
Mountain	3000-6500	0.27-0.59	Estimated area range covers all landmassthathas risen significantly above sea level and the surrounding areas, forming altitudinal gradient-defined vegetation zones of Afro- montane, Ericaceous and Afro- alpine
Forest and Woodland*	173500 - 300,000	15.7-27	This ecosystem includes all forest lands and woodlands in all landscapes.
Aquatic and Wetland	9318	0.844	Covers all wetlands and water bodies
Rangeland	767, 000 (Mengistu et al. 2018)	69	Uncultivated land areas that provide forage and pasture for grazingandbrowsinganimals.They are areas where natural rainfall variability is high, and climatic and other environmental conditions limit crop production
Agro- ecosys-tem	105,974-242,880	9.6-22	Croplands that cover large areas in the highlands and mid-altitude areas,pastorallivelihoodsystems in the lowlands; are grouped into Cereal/grain crop-based, Perennial crop-based, Pastoral and agro- pastoral systems.

***Mountain ecosystem*s:** the mountain ecosystem has declined in area coverage of important vegetation types. Most of the endemic flora and fauna of these isolated mountain ecosystems have been assigned critically endangered status by the IUCN Red List Criteria. The direct drivers of this change are land use and land cover change and increased climate variability, while population pressure is the major indirect driver. The steep slopes in the high-altitude range are encroached by agricultural cultivation and overgrazing. This ecosystem is highly vulnerable to the adverse impacts of climate change. The assessment has also indicated that there is limited research and documentation about the mountain ecosystem of the country.

***Forest and woodland ecosystem*:** this ecosystem is vast and comprises various vegetation types distributed in agro-climatic gradients stretching from the lowland woodlands to the high mountain tropical forests. Past trends showed that deforestation and forest degradation have been rampant and threatened biodiversity in the forests and woodlands. Protected areas that are largely embedded within this ecosystem are facing extreme anthropogenic pressure and becoming more and more vulnerable. Continuous deterioration in natural habitats and a decline in the number of flora and fauna are very common. The continued deterioration of ecosystem services hampered production and threatened human well-being. Among the many, failure to comply with and implement existing policies, laws and regulations has remained the most important factor. The direct drivers of degradation are subtly driven by the underlying legal and institutional factors. These are absence of land use policy, institutional instability, low capacity of forestry institutions, poor inter-sectoral coordination and lack of synergy between sectors, inadequacy of the forestry legal framework, weak law enforcement, and unclear tenure and forest userrights.

***Aquatic and wetland ecosystem*:** the wetland and aquatic ecosystem is a biodiversity hotspot in Ethiopia encompassing at least 10% of the Ethiopian floral diversity, providing habitat for at least 25% avifaunal diversity and hosting several other mega faunas. However, the wetlands and aquatic ecosystem in Ethiopia is rapidly declining due to degradation caused by excessive human activities. The direct causes are excessive water abstraction; habitat changes due to agricultural practices, drainage agriculture, rapid land-use changes, overgrazing, deforestation, urbanization, h and climate change are major causes of wetland loss whereas population growth constitutes the major indirect driver. The biodiversity of the wetlands and aquatic ecosystems is rapidly declining. As a result, those associated with wildlife and floral diversity are highly likely to decline. Besides, the traditional wetland related knowledge systems and their contribution toward conservation and wise use of resources therein are vanishing. The major factors for the degradation and loss of wetlands are population growth, unmanaged urban expansion and encroachment to wetlands, international trade and agricultural investment, and the absence of a national policy that recognizes the values and benefits of wetlands and aquatic resources. Climate change is expected to exacerbate all the direct and indirect drivers.

***Rangeland ecosystems*:** the rangelands in Ethiopia have been shrinking since the 1960s due to extensive land use changes. The management systems are also gradually changing due to the expansion of enclosure systems leading to increased degree of private ownership of grazing lands. The expansion of various forms of enclosures and associated land-use changes curtailed seasonal mobility between wet and dry season

grazing areas, causing continuous grazing and resulting in loss of vegetation cover and soil erosion. Climate change and increased human pressure are aggravating the deterioration of the ecosystem. This is seen in the increasing rate of soil erosion, loss of palatable grasses, and rapid expansion of bush encroachment. The shift towards sedentarization, crop cultivation and privatization of the communal rangelands in pastoral areas is causing serious conflicts among communities. The prevailing policy, governance systems, and institutions emphasize poverty reduction and development efforts focusing on resource extraction aimed at short term gains at the expense of long term biodiversity conservation and sustainability. This has been progressively weakening the customary institutions leading to declines in rangeland biodiversity and ecosystem services.

***Agro-ecosystem*:** Ethiopia's agro-ecosystem, agricultural biodiversity and their services to human wellbeing are seriously affected by natural and anthropogenic drivers of change (climate change, recurrent droughts, floods, acidification, etc), resulting in disasters identified to have significant effects on biodiversity for food and agriculture in Ethiopia. The ecosystem is highly vulnerable to climate change and the spread of invasive alien species (IAS), which negatively affect crop and livestock production and productivity as well as human health. The agroecosystem is negatively affected by unsustainable utilization of resources either in the form of overexploitation or excessive use of nutrients with dire consequences of soil erosion, water depletion, acidification and salt accumulation. There is a growing need to increase production and productivity in order to provide food for the growing population and to reduce poverty, while managing agro-biodiversity and agro-ecosystem services in a sustainable manner to maintain healthy human ecology and socioeconomic wellbeing.

1.7.8. Waste management

Although Ethiopia has ratified most conventions related to waste management and handling (e.g., Basel, Stockholm, and Rotterdam conventions), and passed sound policies and legislations to manage waste, there is clear lack of sound management of environmentally hazardous chemicals and wastes. Existing policies and laws on waste management are not strictly implemented. Waste generation is directly linked to population growth and urbanization. As the total population and the number of urban dwellers has been increasing annually, the waste generation has increased from 9,700 ton/day in 2015 to 12,200 ton/day in 2020. By 2030, the waste generation rate at national level will be doubled from that of the 2015, i.e. 24,400 ton/day. In the past few years, most municipalities in Ethiopia have become aware of the negative consequences of poor sanitation and poor handling of waste on public health. Studies show that most small and medium cities have devised and adopted a system of collecting and disposing off solid waste. A survey of the waste management system in randomly selected cities such as Dessie, Bahir Dar, Mekele and Nazareth, and medium towns such as Woldiya, Axum, Robe, Gimbi, Adwa and Arbaminch, show that, i.e., 86.6 % used open dump to dispose waste, while the rest are using dumping pit holes. Other towns use open dump for waste disposal, causing pollution to surface and ground water. However, from the total generated waste, only 40 % is collected and properly disposed while only 4 % is recycled (Hirpe and Yeom, 2021).

Ethiopian imports various types and large quantities of industrial products because of the low capacity of local industries and the lack of raw materials, like plastic, aluminum, chemicals, rubber, iron bars, paper and variety of construction materials. Because the limited supply of finance, there is high demand for industrial products from outside. In this regards, recycling can play a crucial role in solving the vicious cycle by creating a supply of raw materials in the country. Ethiopia is the second largest importer of plastic raw materials from east and central African countries. The current amount of plastic consumption in Ethiopia is about 386,000 ton/year. Due to a lack of technology, investment and experience only, 30–40% of the plastic waste is recycled. Water bottling industries sell about 3.5 billion bottles of water annually. To the contrary, there are only tem plastic bottle recyclers and there a great deal of loss of plastic bottles as waste. Similarly, Ethiopia imports huge amounts of paper at a very high cost. There are only 15 formal and informal paper recyclers in the country and collectively they recycle only about 5% of the disposed paper. An estimated amount of more than 200 Mt of paper and cartons are wasted in dump sites, burned or left on the streets as a garbage.

1.8. Economic and Financial Performance

1.8.1.Economic growth

Ethiopia has registered notable economic growth and considerable poverty reduction In the last decades. Key issues relating to the sustainability of growth have arisen as the growth has been largely driven by public investment in infrastructure, resulting in government debt and fiscal space concerns. As shown in Fig. 1.31 below, real GDP has increased from $8.24 billion in 2000 to $29.93 billion in 2010 and $84.3 billion in 2018 (). GDP growth between 2001-2010 averaged 8.74% . In the periods between 2011-2018, GDP has grown with average of 9.73% annually.

below shows the trends of GDP per capita for the periods between 2000-2018. As shown in the Figure, the per capita income which was $124 in 2000 has reached 342 in 2010 and $772 in 2018.

Figure 33 Trends of Real GDP and GDP growth rate (2000-2020)

Source: Macrotrends (2018)

In terms of sectoral contribution to growth, the service sector has been the main driver despite the government's policy of focusing on agriculture and industry (Martins, 2014; Ferede and Kebede, 2015; World Bank, 2016; Office of the Prime Minister, 2019

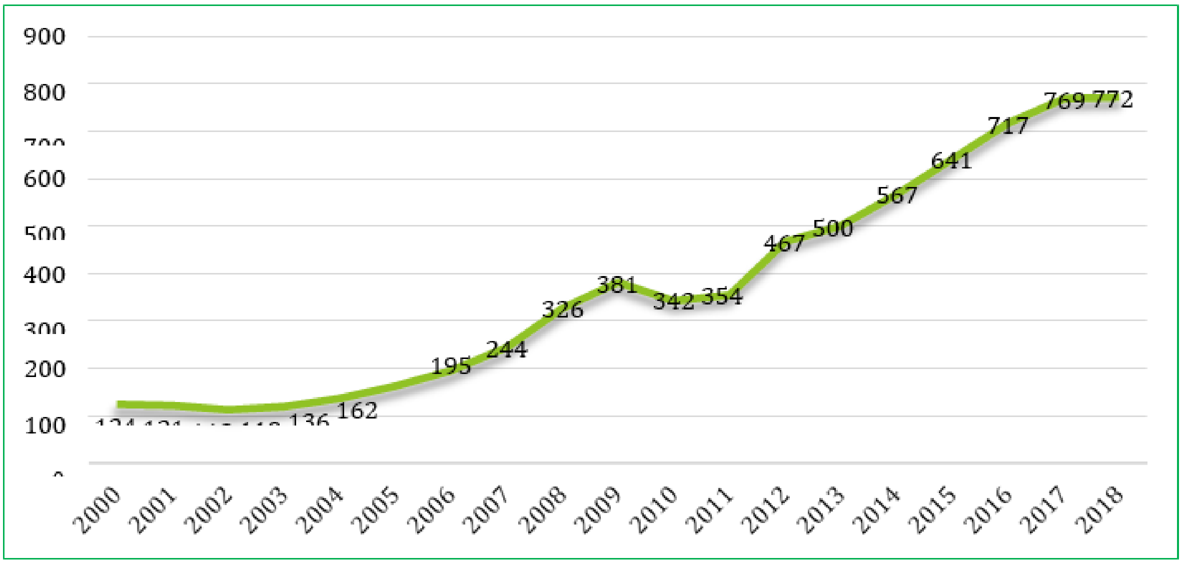

Figure 34 Trends in GDP per capita (2000-2018) Source: Macrotrends (2018). Available at Ethiopia Economic Growth 1981-2018 | MacroTrends

As a result, despite structural transformation being the focus of government policies over the last decade, as underlined in the first Growth and Transformation Plan (2010– 2015) andthesecondGrowth andTransformationPlan(2015–2020),achievementshave been less than hoped (NPC, 2016).

Ethiopia's strong economic growth has helped to achieve social gains across sectors and halved poverty over the past decade. One of the simples' measures of poverty is the head count index. The headcount index (P0) measures the proportion of the population that is poor. As shown in Figure, the incidence of poverty (poverty headcount) which was 45.5% in 1995/1996, has declined to 38.7% in 2004/05 and then to 23.5 % in 2015/16. The poverty gap index (the ratio by which the mean income of the poor falls below the poverty line) and poverty severity index (inequality among the poor) have declined from 12.9 and 5.2 to 6.7 and 2.8 in the years 1995/96 and 2015/16 respectively The sharp decline in poverty is attributed to economic growth and partly to the implementation of social protection programmes, such as the Productive Safety Net Programme (PSNP), as well as urban food distribution and subsidies. Despite the reduction in poverty headcount, food poverty is high, with a large share of household spending going on food. Thus, food security is a concern that remains on top of the national agenda (UNICEF, 2017).

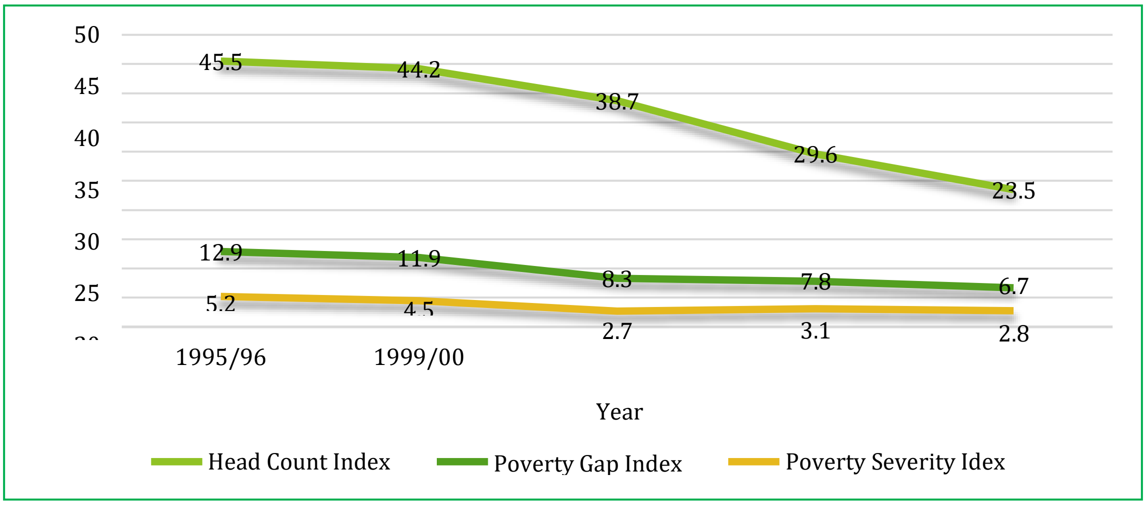

Figure 35 Trends in national poverty level

Source: CSA-HICE (1998, 2001, CSA 2010, 2012, 2018)

GDP growth in terms of absolute growth was led by industry (7.3%), services (5.5%), and agriculture (5.5%) on the supply side and private consumption and investment on the demand side. However, as indicated in Figure 6, the service sector (40%) has received the most considerable proportion of GDP in the economy in the consecutive years, followed by agriculture (37%), and industry (23%). The contribution of the industrial sector to GDP has been increasing, albeit from a low base. This low level indicates that economic transformation has yet to take shape. To bring sustainable transformation of the economy, the Government of Ethiopia needs to promote private investment, particularly in the strategic priority area of the agro-processing manufacturing sector and strengthen the industrial base.

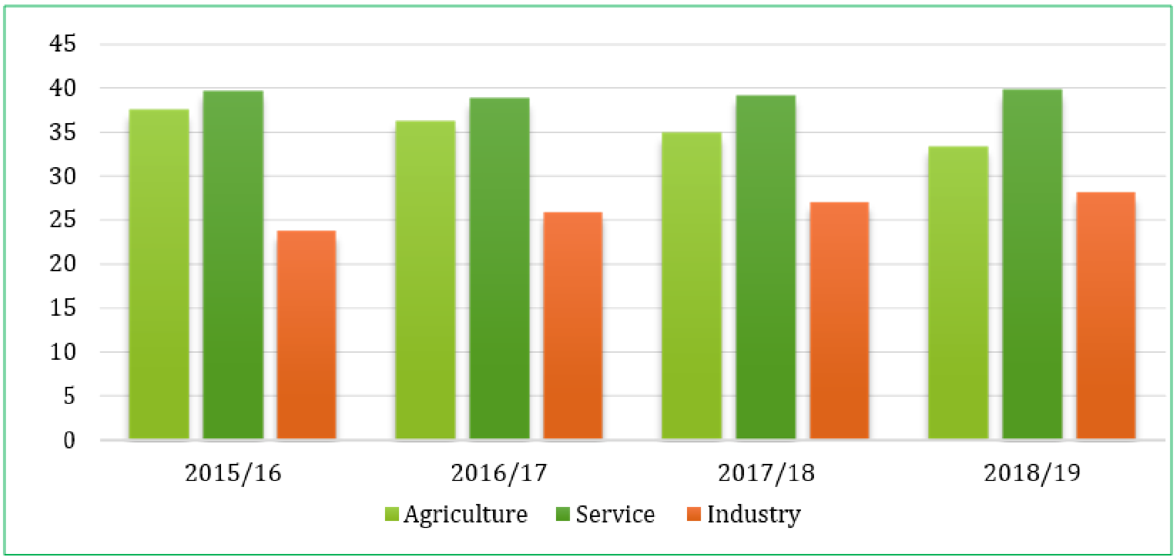

Figure 36 Share of the economic sector in GDP

Source: NPC,2017/18; NBE, 2018/2019

Regarding sectoral contribution to GDP growth, the service sector accounted for the highest 38.3% in 2020/21, with a varying and slowly declining proportion in comparison to 2018/19 (). Next to the service sector, the industry sector contributed 33,6 % to the overall GDP growth. On the one hand, the agriculture sector contributed the lowest, 29 %, compared to other sectors. However, on the other hand, its contribution has increased compared to previous years.

Regarding sub-sectors, crop production accounts for 65.1% of the agricultural sector, while animal farming & hunting, and forestry each account for 8.6%. While crop production increased by 5.7%, animal farming & hunting and forestry increased by 5.8% and 3.9%, respectively. Manufacturing is the industry sector that contributed to 23.4% of the total industrial production. The construction industry registered a 6.6 % expansion with a 72.2 % share in industrial output, with roads, railways, dams, and residential house construction playing a significant role. The mining and quarrying sector's expansion trend was maintained in 2020/21, with a 115.4% increase (NBE, 2017/18 Annual Report).

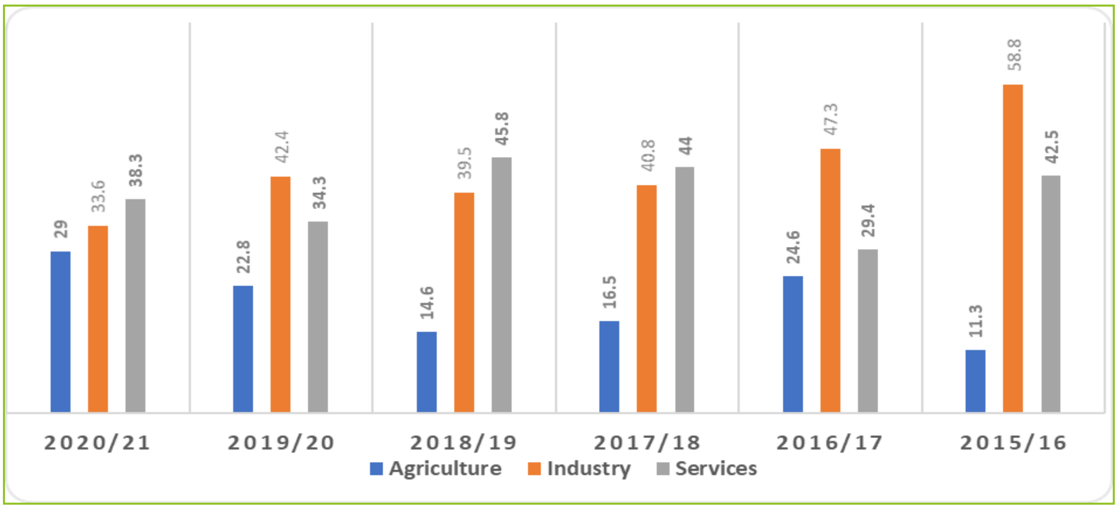

Figure 37 Sectoral Share to GDP Growth in %

Source: NPC,2020/21 NBE, 2020/2021

The service sector continued to dominate the economy in 2020/21 as its share of GDP; the 6.3 % growth in the service sector was attributed mainly to the expansion of real estate, renting & business activities (8.9 %), transport & communication (7.0 %), wholesale & retail trade (6.3 %), other services (6.2 %), public administration&defense(4.9%)and hotels & restaurants (2.6 %) (NBE, 2020/21 Annual Report).

1.8.2.Poverty and inequality

In terms of the 'war on poverty', substantial progress has been registered in the last two decades. Ethiopia's strong economic growth has helped to achieve social gains across sectors and halved poverty over the past decade. One of the simplest measures of poverty is the head count index. The headcount index (P0) measures the proportion of the population that is poor. As shown in Figure, the incidence of poverty (poverty headcount) which was 45.5% in 1995/1996, has declined to 38.7% in 2004/05 and then to 23.5 % in 2015/16. The poverty gap index (the ratio by which the mean income of the poor falls below the poverty line) and poverty severity index (inequality among the poor) have declined from 12.9 and 5.2 to 6.7 and 2.8 in the years 1995/96 and 2015/16 respectively (World Bank, 2015). The sharp decline in poverty is attributed to economic growth and partly to the implementation of social protection programmes, such as the Productive Safety Net Programme (PSNP), as well as urban food distribution and subsidies. Despite the reduction in poverty headcount, food poverty is high, with a large share of household spending going on food. Thus, food security is a concern that remains on top of the national agenda ((World Bank, 2015). Figure 27**Error! Reference source not found.** below shows the trends in poverty.

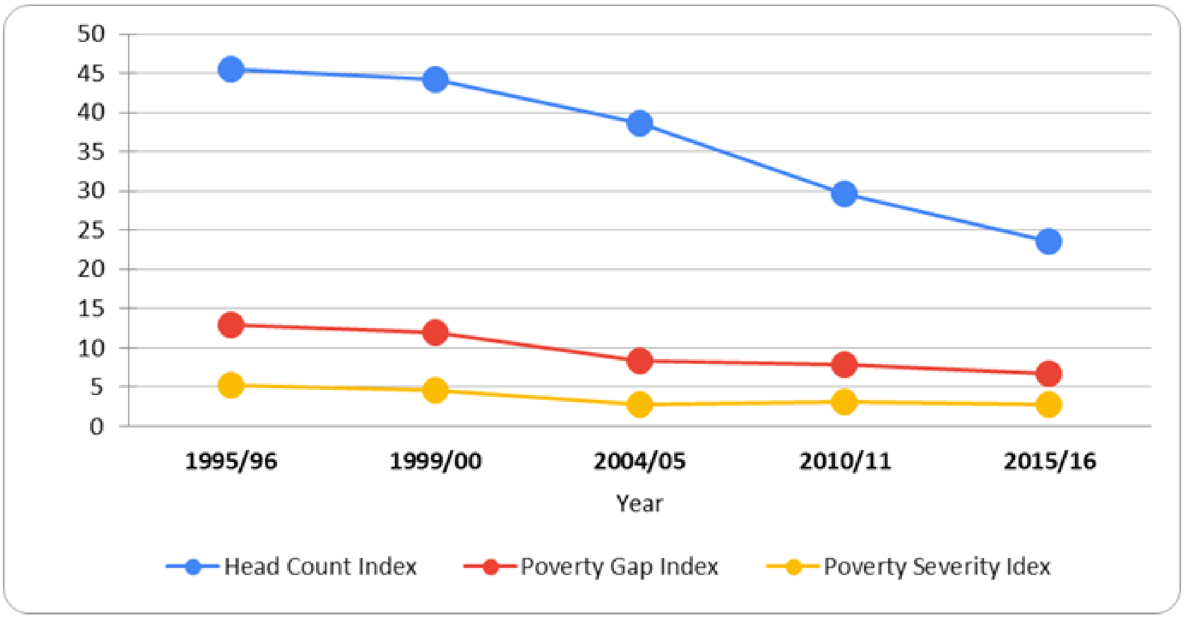

Figure 38 Trends in national poverty level

Source: CSA-HICE (1998, 2001, CSA 2010, 2012, 2018)

Poverty reduction has been, however, followed by a small increase in inequality. Indeed, income inequality (measured using the Gini coefficient) has increased since the mid- 1990s. In 1995/96, estimates placed Ethiopia's national Gini coefficient at 0.29, compared with0.33in2015/16(NPC,2017).This small increase has mainly been driven by growing differences in terms of income and access to certain services between urban and rural households.Nevertheless,Ethiopiaremainsthecountrywiththelowest levelofinequality intheregion.AmongEastAfricancountries,Ethiopiaranksatthebottomintermsofboth the Gini coefficient and the difference in income shares between the richest 10% and the poorest 10%. Ethiopia's Gini coefficient (0.33) is followed by Sudan's and Mauritius', both estimated at 0.35. At the other end of the ranking, Kenya and Rwanda show the highest values, at 0.48 and 0.50, respectively. In terms of the difference in income shares, Ethiopia stands at 8.6. In other words, the richest 10% of the population is 8.6 times richer than the poorest 10%. This contrasts with countries such as Kenya or South Sudan,where this statistic reaches 22.8 and 25.5, respectively (NPC, 2017).

1.8.3.Human development

In the past decades, there has been significant progress in human development, in health service coverage, child mortality, life expectancy at birth, access to clean water, primary school enrolment and literacy. The pre-primary and primary education net enrolment rate has increased over the past decades. Similarly, the health sector has registered substantial progress in improving health outcomes in a number of areas, including under-five mortality rate, primary health coverage, postnatal care coverage and contraceptive use.

The HDI is a summary measure for assessing long-term progress in three basic dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. A long and healthy life is measured by life expectancy. Knowledge level is measured by mean years of schooling among the adult population, which is the average number of years of schooling received in a life-time by people aged 25 years and older; and access to learning and knowledge by expected years of schooling for children of school-entry age, which is the total number of years of schooling a child of school-entry age can expect to receive if prevailing patterns of age-specific enrolment rates stay the same throughout the child's life. Standard of living is measured by Gross National Income (GNI) per capita expressed using international dollars converted using purchasing power parity (PPP) conversion rates. The Table 23**Error! Reference source not found.** below shows the trends in HDI measures and HDI for the period 1990-2019.

Table 23 Trends of HDI in Ethiopia (1990-2018)

Year	Life Expectancy at birth	Expected Yearsof schooling	GNI per capita (2017 PPS$)	HDI value
1990	47.1	3.1	763	
1995	49.3	2.5	671	
2000	51.9	4.3	726	0.292
2005	56.2	6.6	863	0.355
2010	61.6	8.2	1,257	0.421
2015	65	8.7	1,772	0.462
2016	65.5	8.6	1,889	0.467
2017	65.9	8.6	2,010	0.474
2018	66.2	8.7	2,094	0.478

(Source: UNDP (2018)

Above, the country has shown improvement in life expectancy at birth, years of schooling and GNP per capita. For instance, the average life expectancy at birth has increased from 47 years in 1990 to 67 years in 2019. Likewise, expected years of schooling have increased from 3 years in 1990 to 9 years in 2019. Between 1990 and 2019, Ethiopia's life expectancy at birth increased by 19.5 years, mean years of schooling increased by 1.4 years and expected years of schooling increased by 5.7 years. Ethiopia's GNI per capita increased by about 189.3 percent between 1990 and 2019. Same is true for GNP per capita. Ethiopia's HDI value for 2019 was 0.485-which put the country in the low human development category-positioning it at 173 out of 189 countries and territories. Between 2000 and 2018, Ethiopia's HDI value increased from 0.292 to 0.485, an increase of 66.1 percent.

The HDI is an average measure of basic human development achievements in a country. Like all averages, the HDI masks inequality in the distribution of human development across the population at the country level. The 2010 Human Development Report introduced the IHDI, which considers inequality in all three dimensions of the HDI by 'discounting' each dimension's average value according to its level of inequality. The IHDI is basically the HDI discounted for inequalities. The 'loss' in human development due to inequality is given by the difference between the HDI and the IHDI, and can be expressed as a percentage. As the inequality in a country increase, the loss in human development also increases (UNDP, 2020). Ethiopia's HDI for 2019 is 0.485. However, when the value is discounted for inequality, the HDI falls to 0.348, a loss of 28.2 percent due to inequality in the distribution of the HDI dimension indices. Rwanda and Uganda show losses due to inequality of 28.7 percent and 26.7 percent, respectively. The average loss due to inequality for low HDI countries is 31.4 percent and for Sub-Saharan Africa it is 30.5 percent. The Human inequality coefficient for Ethiopia is equal to 27.3 percent (UNDP, 2020).

In the 2014 Human Development Report, a new measure- GDI was introduced based on the sex disaggregated HDI, defined as a ratio of the female to the male HDI. The GDI measures gender inequalities in achievement in three basic dimensions of human development: health (measured by female and male life expectancy at birth), education (measured by female and male expected years of schooling for children and mean years for adults aged 25 years and older) and command over economic resources (measured by female and male estimated GNI per capita). The GDI is calculated for 167 countries. The 2019 female HDI value for Ethiopia is 0.442 in contrast with 0.527 for males, resulting in a GDI value of 0.837. In comparison, GDI values for Rwanda and Uganda are 0.945 and 0.863, respectively (UNDP, 2020).

1.8.4. Sources of finance

The government of Ethiopia has used deficit financing for acquiring funds to finance economic development. When the government cannot raise enough financial resources through taxation, it finances its developmental expenditure through borrowing from the market or from other sources. Figure 1.37 below shows the sources of finance for the federal budget.

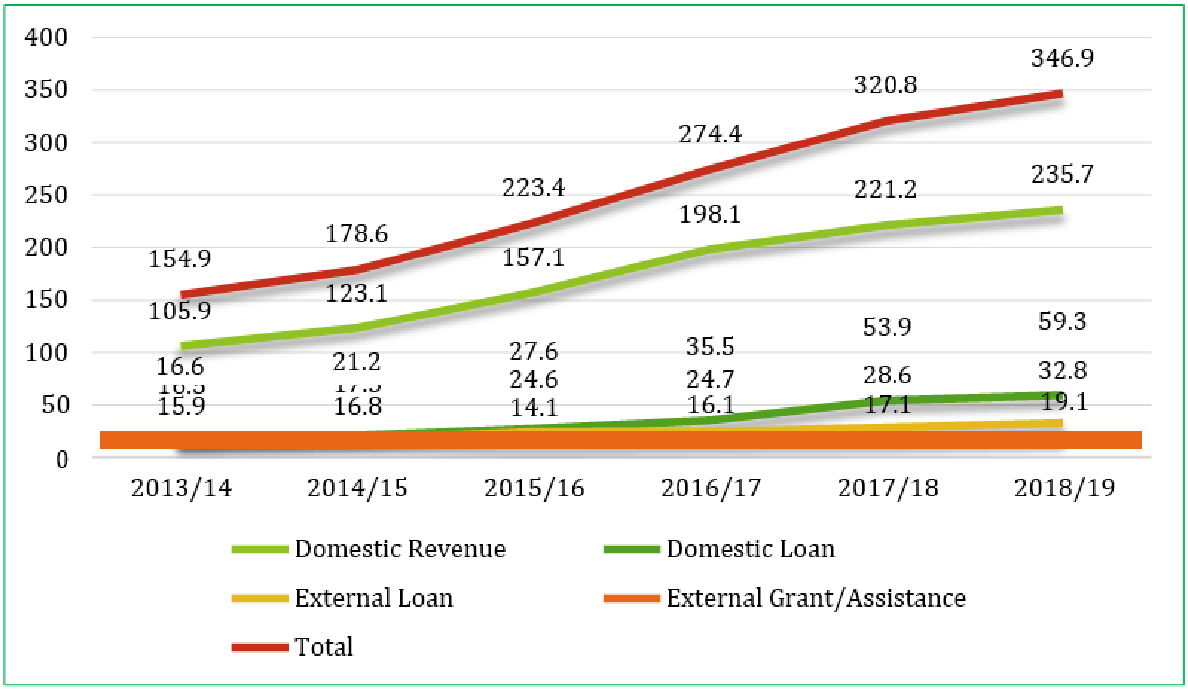

Figure 39 Sources of Ethiopian government finance (2013/14-2019/20)

Source: Ministry of Finance

As indicated in Figure 38 above, the government budget has dramatically increased from year to year. The total government budget, for example, increased from 154.9 billion birr in 2013/14 fiscal year to 346.9 billion in 2018/19 fiscal year. This is an increment of 150% in the years between 2013/14- 2018/19. Yet domestic revenue remains the primary sources of finance for the government accounting, on average, for about 69% in the periods between 2013/14 and 2018/19 fiscal year. External grant/assistance from bilateral and multilateral development partners also contributes much to national budget accounting for about 7% of the national budget. See below. Total of Birr 478.9 billion revenue (including grants), was collected in 2020/21 depicting 21.2 % annual growth from 2019/20. Of the total revenue, domestic revenue, at Birr 444.6 billion registered a 25.5 % year-on-year surge. About 87.4 % of domestic revenue was generated from taxes and 12.6 % from non-taxes. Tax revenue expanded by 24.8 %, mainly owing to 31.6 % growth in direct taxes, which comprise income & profit taxes and urban & rural land use fees. Income and profit taxes alone accounted for 97.6 % of the direct taxes. On the other hand, Birr 214.8 billion was collected from indirect taxes which constituted 55.3 % of the total tax revenues.

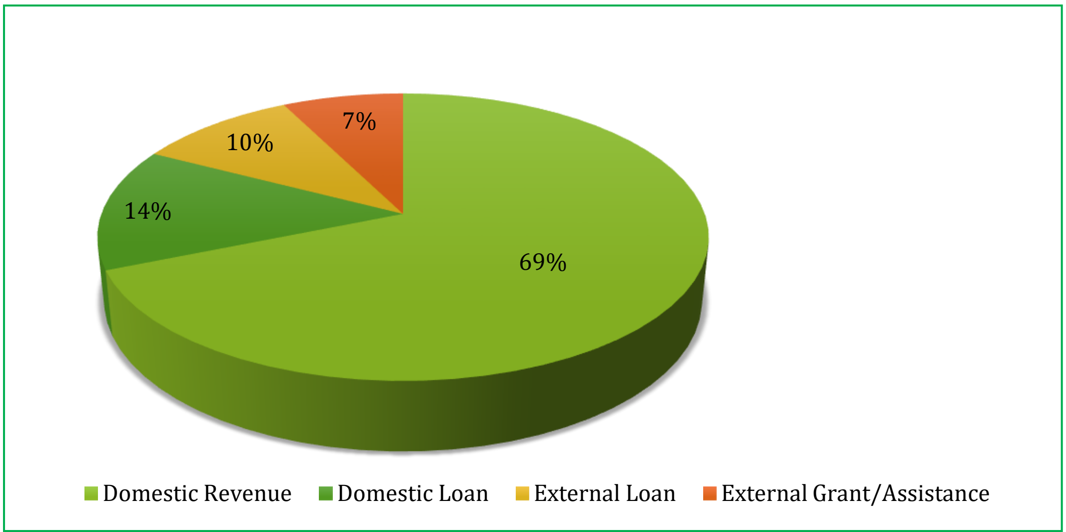

Figure 40 Share of financing sources out of the total federal budget (2013/14-2017/18)

National development and climate change policies

1.8.5.Broader economic development policies

Since the 1990s. economic policies and strategies in Ethiopia have been developed against the framework of the Agricultural Development Led Industrialization (ADLI) strategy (Robele, 2014). ADLI was prepared based on the development theories of the 1960s in which smallholder agriculture needs to be developed first to facilitate demand for industrial commodities and inputs for industrialization (Dube eta al., 2019). The development of this strategy was justified as agriculture is the largest sector in terms of output and, particularly, employment and exports. The justification is also because the majorities of the poor live in rural areas and considerable gaps exist between rural and urban in health, education and income levels (Rolebe, 2014).

Following ADLI, two consecutive five-years national development plans were prepared, accompanied by sector development plans for education, health, road and others. The first is the 2002-2005 Sustainable Development and Poverty Reduction Program (SDPRP). During SRPRP, the agricultural sector, along with social services such as education and health and physical infrastructure such as roads, received due attention (MoFED, 2002). This plan was followed by the Plan for Accelerated and Sustained Development to End Poverty (PASDEP). PASDEP covered a period from 2005 to 2010 and is formulated based on SDPRP (Abeba, 2006). One of the pillars of PASDEP was the promotion of entrepreneurship schemes in the country. Entrepreneurship schemes were aimed at creating employment opportunities focusing on labor-intensive industries through the promotion of Medium and Small Enterprises During the PASDEP period, the economy indeed grew on average by 11% but the the structural transformation from agriculture to industry was not achieved as expected (NPC, 2016).

The above two five years development plans were followed by GTP I and GTP II covering periods from 2011-2020. During the first Growth and Transformation Plan (GTP) which ran from 2011 to 2015, and the second GTP from 2015 to 2020, the industrial sector received substantial support still maintaining agriculture as the main source of growth (NPC, 2016). During the two GTPs, emphasis was given to transforming the economy from agriculture to industry and to higher value services' sector. Besides, various support schemes were directed towards selected export-oriented and import-substitution sectors such as textiles, leather goods, cement, and pharmaceuticals (NPC, 2016). Heavy government investment on infrastructure was also expected to enhance the competitiveness of the private sector (Gebreeyesus,2013).

Economic policies and strategies over the last decades have brought economic growth accompanied by a substantial reduction in poverty (IMF, 2013). However, the extent of public investment has been one of the key factors which have led to concerns of debt sustainability, and the private sector has failed to operate as expected, raising sustainability concerns of economic growth. Key private sector challenges have included supply–side challenges such as logistics, foreign exchange shortages, slow customs clearance, and the poor quality and unavailability of inputs.

Climate change is acknowledged as a threat in GTP I period. The plan indicates that Ethiopia's economy already suffers annual losses between 2%-6% due to climate change impacts on total production (MoFED, 2010). Both climate adaptation and mitigation measures are identified as important elements toward a green development pathway for the country. GTPI makes reference to the development of a plan of "action, strategies, laws, standards, and guidelines to implement measures that are designed to lessen the effect of future climate change impacts" (MoFED, 2010). It also notes that measures to support climate change action in the country include capacity building for private and public stakeholders for fundraising, allocation of local and foreign technologies for climate change mitigation, increased awareness of and knowledge sharing on environmental management practices, and ratification of international environmental laws and protocols (MoFED, 2010).

The second growth and transformation plan GTPII (2016-2020) states that Ethiopia to be becoming a lower-middle-income country by 2025. Among the various objectives one is building a climate resilient and green economy. The plan suggests that the government's climate adaptation priorities will focus on improving food security, improving the incomes of farmers and pastoralists, expanding renewable electricity production, and protecting and rehabilitating forests. GTP II also identifies objectives related to improving productivity in the agricultural sector, addressing critical infrastructure gaps, strengthening public institutions and governance, and empowering women and youth. It focuses on Climate Smart Agriculture as a strategic approach helping to achieve the objectives of reducing greenhouse gas emissionthroughenhancingproductivityofthecropandlivestock(NPC, 2016).

1.8.6.Ethiopia's Policy Response to Climate Change

Ethiopia is vulnerable to climate change shocks. Its climate change vulnerabilities include drought, flooding, desertification, water scarcity, and increased incidence of pests, affecting the agriculture, energy, and health sectors. Ethiopia's climate is highly variable, both spatially and temporally, and projections suggest that this variability will continue alongside rising temperatures. This has significant implications for efforts to reduce poverty and food insecurity in the country. To address these challenges, and to achieve economic growth and prosperity, the country needs to reduce vulnerability in key sectors such as agriculture, water, and health, while improving the adaptive capacity of poor individuals and communities (Echeverria & Terton, 2016). The country's adaptive capacity is, however, constrained by limited livelihood options for the majority of the population, inadequate ability to withstand or absorb disasters and the prevailing biophysical shocks (Endalew,2016).

To address climate related challenges, there was a need for stronger climate change adaptation policies, programs and implementation capacity across sectors, levels of intervention and actors (MoA 2014; MoWE, 2015). Recognizing impacts of climate change, Ethiopia is a leader on climate change action in Africa and amongst least developed nations to develop policies, strategies, and institutional frameworks for climate action to advance an effective climate change response in the country. Before many nations, Ethiopia has established climate change legislations, policies, plans, and institutions at national and sub-national levels. Ethiopia's policy framework for climate change mitigation and adaptation has progressively evolved since the ratification of the UNFCCC in 1994. More than 70 climate and environment related strategies, polices, programs including the national policy measures and international conventions have been in place in Ethiopia (see the summary of all these in annex). Through its medium- term development plans and strategies, Ethiopia has also been integrating climate change and sustainable development principles as of early 2000. However, the CRGE Strategy (2011) is the first national policy document on strategically focused climate change responses (Echeverria & Terton, 2016).

Prior to the CRGE strategy the Ethiopian Constitution, The Environmental Policy of Ethiopia in 1997, the Environmental Impact Assessment Proclamation in 2002; the Rural Development Policy and Strategies (RDPS) in 2003, the 2007 Forest Management, Development and Utilization Policy; the Forest Development, Conservation and Utilization Proclamation (542/2007); the National Adaptation Plan of Action (NAPA) in 2007 (Ethiopian Meteorological Agency, 2007) and Ethiopian Program of Adaptation to Climate Change (EPACC) in 2011 and Nationally Appropriate Mitigation Actions in 2010 were in place as part of Ethiopia's pledge to control the impacts of climate changein the country. The EPACC has called for the mainstreaming of climate change into decision-making at a national level and emphasized planning and implementation monitoring. It identified 20 climate change risks, mainly health risks (human and animal); agriculture production decline; land degradation; water shortages;

biodiversity;waste; displacement; and distributive justice. It follows a more programmatic approach to adaptation planning. Seeks to build a climate resilient economy through adaptation at sectoral, regional and community levels. The EPACC updates and replaces Ethiopia's National Adaptation Program of Action (NAPA) which was formulated in 2007 and submitted it to the UNFCCC Secretariat (Echeverria & Terton, 2016).

In addition, parallel to the GTP I, in 2010 Ethiopia released the Environmental Management Programme of the Plan for Accelerated Sustainable Development to Eradicate Poverty of 2011–2015 (EPA, 2010). Among its goals was enhancement of national, subnational, and sectoral capacity to mainstream actions that will build a carbon neutral and climate resilient economy. To achieve this goal, the plan seeks harmonization of all national policies, strategies, laws, programs, and governmental documents, to the extent possible, with efforts to address climate change adaptation and mitigation (EPA, 2010). The environmental management plan also includes the integration of scientifically sound solutions for manufacturing industries and the infrastructure needed for poverty eradication to adapt to climate change impacts; the evaluation of climate change vulnerability in a number of freshwater resources and formulation of adaptation actions to reduce their sensitivity (EPA, 2010). The development of measurable and verifiable targets identified by each regional and government level for the development of a climate resilient, carbon neutral economy during 2010–15 was also the objective of EMP (EPA, 2010). The other two goals include the creation of carbon credits to diversify renewable energy generation and reforestation, and the enhancement of socioeconomic goods and services through enforcement of and compliance with environmental laws (EPA, 2010).

The CRGE strategy sets that by 2025 Ethiopia will be a middle--income country, resilient to climate change impacts and with no net increase in greenhouse gas emissions from 2010 levels (Echeverria & Terton, 2016). The strategy has identified four priority sectors as instrumental for reaching middle-income status by 2025, namely agriculture; forestry; power; and industry, transportation, and buildings. Sectoral plans for development and climate change adaptation and mitigation needs have also been developed (FDRE, 2015a). The strategy has also identified four pillars of development in the green economic action plan:(a) improve crop and livestock production practices for higher food security and farmer income while reducing emissions;(b) protect and re-establish forests for their economic and ecosystem services, including as carbon stocks;(c) expand electricity generation from renewable sources of energy for domestic and regional markets; and leapfrog to modern and energy-efficient technologies in transport, industrial sectors, and buildings. The leading agency conducting the efforts of the CRGE strategy was the Environmental Protection Authority (EPA), backed by the National Environment Policy Organs Establishment No. 295/2002 (FDRE, 2015).

However, the CRGE strategy has focused on the climate change mitigation aspects and did not specifically address climate change adaptation. The gap was recognized and rectified through the development of sectoral climate resilience strategies – for the agriculture and forestry sectors, the water and energy sectors, the transport sector, urban as well as health sectors (Echeverria & Terton, 2016). Yet, without a specific mention of adaptation, Ethiopia has been implementing massive development interventions since early 2000s, most of which contribute to greater adaptive capacity and increased resilience (Endalew, 2016). More strategically from 2011, a large proportion of adaptation activities took place in the agriculture sector, focused on soil, water conservation and crops, as well as in the livestock management and water resource development for hydropower and irrigation sectors. These included large flagship resilience projects such as the Productive Safety Net Programme (PSNP), the Agricultural Growth Programme (AGP), the Sustainable Land Management Programme (SLMP), the Participatory Small- scale Irrigation Development, and the ONE-Wash programme. Likewise, large-scale REDD+ interventions are implemented across the country that contributed to adaptation, even as they are predominantly designed to have mitigation impacts through reducing emission from deforestation and enhancing carbon sequestration (Echeverria & Terton, 2016).

As part of its commitment, Ethiopia submitted to the UNFCCC its initial national communication (INC) in 2001 and its second national communication (SNC) in 2015. Ethiopia submitted its Nationally Determined Contributions/NDC to the UNFCCC on June 2015 which later converted to Ethiopia's 1st NDC after Ethiopia ratified the Paris Agreement in March 2017. Ethiopia's 1st NDCs has specific aims to reduce emission to 145 Mt CO_2eq or lower by 64% from a business-as-usual trajectory by 2030 and also to reduce societal vulnerability to climate shocks by undertaking series of adaptation initiatives. Both strategies, CRGE and NDCs, are therefore well aligned to each other and are considered as an implementing mechanism of addressing climate change challenges. To advance the integration of climate change adaptation and mitigation into the national planning, policy and budgeting process, Ethiopia has continued developing and refining a comprehensive CRGE/NDCs strategy. The National CRGE has lay out the detailed guidelines and framework outlining the sectors strategies and priority actions to climate change adaptation and mitigations and their contributions to the nationally determined targets (Endalew, 2016; Echeverria & Terton, 2016).

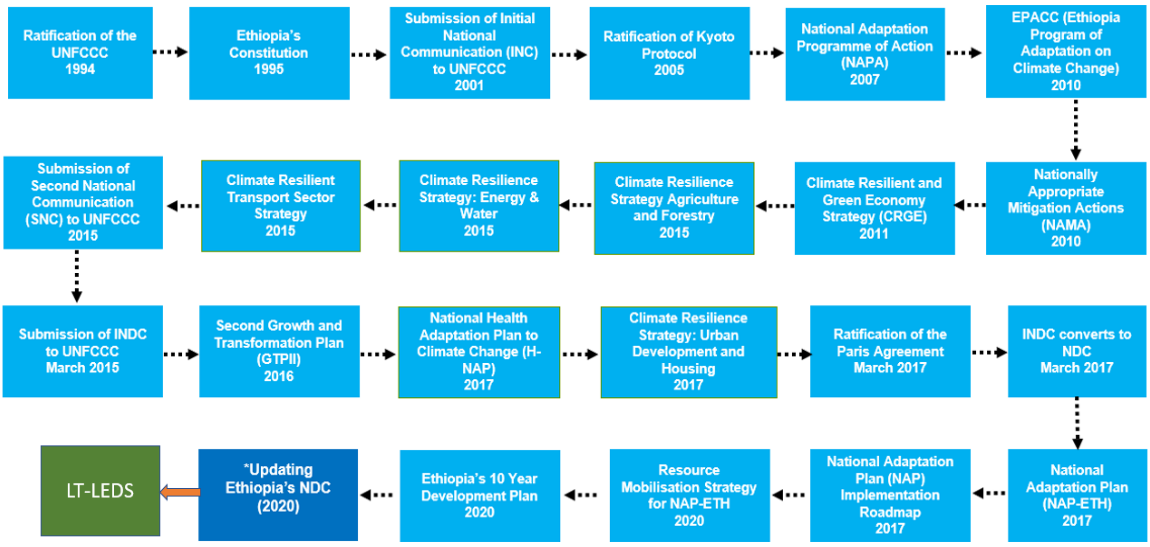

Figure 41 Ethiopian climate change policy roadmap since 1994

Broadly, the climate change policies, plans, and legislations include: the re-establishment of Environment, Forest and Climate Change Commission, development of climate- compatible medium and long-term national plans, Climate Resilient Green Economy Strategy, National Adaptation Plan, the Nationally Determined Contribution, CRGE climate finance facility, REDD+ strategy in 2008, and National Forest Sector Development Program. At the sub national level, local governments are also developing their climate change response plans which have prioritized climate change agendas and adaptation and mitigation measures (Endalew, 2016). These all efforts demonstrate not only Ethiopia's desire to grow economically and become a middle-income country, but also its ambition to build a low carbon and climate resilient economy. presents a summary of Ethiopia's legislative, institutional, policy, programmatic and strategic responses and preparedness to climate change challenges and actions.

1.8.7. Relevant Institutional Arrangements for the Implementation of the UNFCCC

Ethiopian Environmental Protection Authority (FEPA) has passed through different institutional restructuring and changes in its legal formation. The Environmental Protection Authority (EPA), Ministry of Environment and Forest, Ministry of Environment, Forest and Climate Change and Forest and Climate Change commission were key stepping institutions for the establishment of the Environment. Environmental Protection Authority (EPA) was established as an autonomous government agency at the Federal level by Proclamation 9/1995 in 1995. The institution was accountable to the prime Minister. Along with EPA, the Environmental Protection Council was also established to oversee the tasks and activities of EPA as well as the activities of sartorial environmental agencies and units responsible for environmental management. The proclamation establishing EPA also stipulated the need for the establishment of environmental organs byregions.

Following the need for better representation of environmental matters in the Council of Ministers, EPA upgraded to the Ministry of Environment and Forest showing the political will and increased momentum in managing the Environment. EPA was subsequently re-established as an autonomous body responsible to the Prime Minister by the Environmental Organs Establishment Proclamation No. 295/2002. The Ministry of Environment and Forest was established by the amended proclamation 803/2013. In 2015, the Ministry of Environment and Forest was renamed and restructured to the Ministry of Environment, Forest and Climate Change by Promotion No 916/2015. In 2018, the Ministry of Environment, Forest and Climate Change was renamed and restructured to the Environment and Forest and Climate Change Commission, the Environment and Forest and Climate Change Commission was renamed and restructured to the Ethiopian Environmental Protection Authority. The Authority has, the following powers and duties:

- Coordinate measures to ensure that the environment objectives provided under the constitution and the basic principles set out in the environmental policy of Ethiopia are realized.
- Establish a system for environmental impact assessment of public and private projects, as well as social and economic development policies, strategies, laws and programs.
- Prepare a mechanism that promotes social, economic and environmental justice and channel the major part of any benefit derived thereof to the affected communities to reduce emissions of greenhouse gases that would otherwise have resulted from deforestation and forest degradation.
- Coordinate actions on soliciting the resources required for building a climate resilient green economy in all sectors and at all governance levels as well as provide capacity building support and advisory services.
- Establish a system for the evaluation of the environmental impact assessment of investment projects submitted by their respective proponents, the concerned sartorial licensing organ or the concerned regional organ prior to granting permission in accordance with the

EnvironmentalImpactAssessment Proclamation.

- Take part in the negotiations of international environmental agreements and, as appropriate, initiate a process of their ratification.
- Establish an environmental information system that promotes efficiency in environmental data collection, management and use.
- Promote and provide non-formal environmental education program and cooperate with competent organs with a view to integrating environmental concerns in the regular educational curricula.

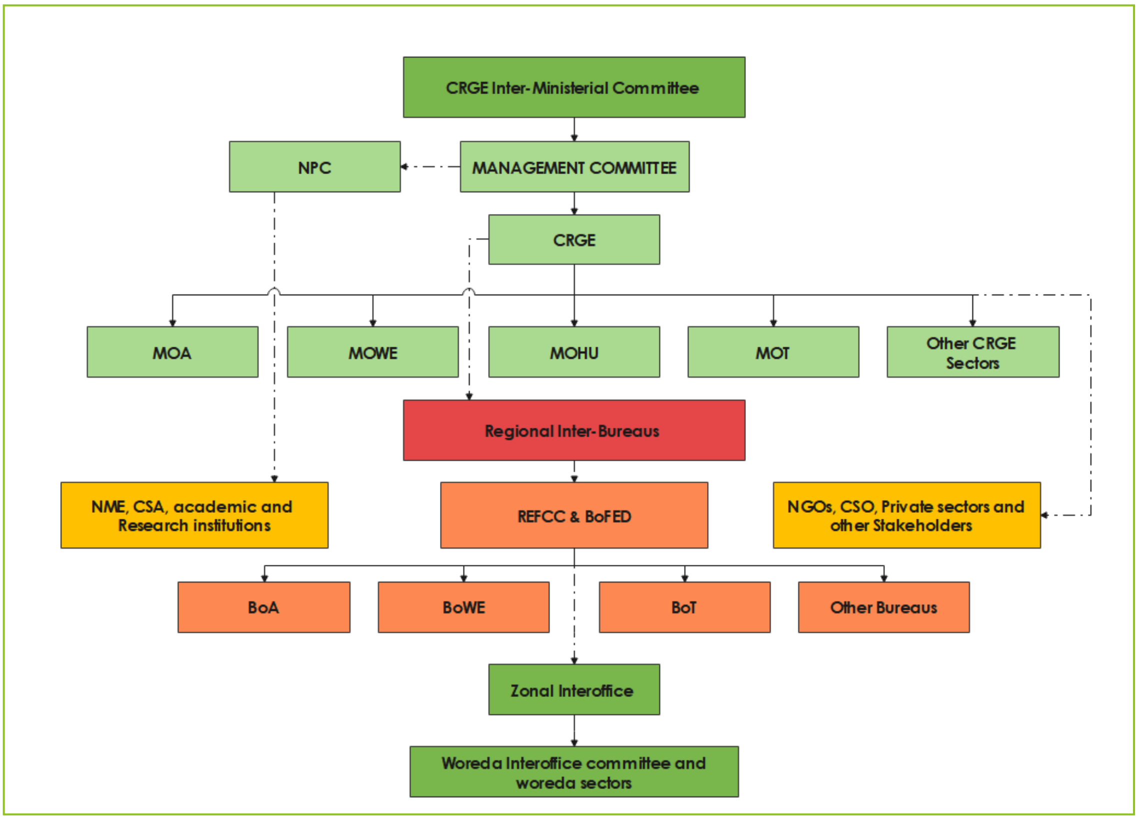

Figure 42 Ethiopia governance arrangements of the CRGE

The country has endorsed a climate-resilient green economic path since 2011 and has registered dramatic economic growth, with an average 9.2% growth rate a year from 2010/11 to 2019/20. The high growth rates have also been accompanied by structural transformation. This is evidenced by the fact that the share of the agriculture sector in GDP decreased to 32.7% in 2019/20 from 45.7 in 2010/11, with the construction and services sectors accounting for the majority of the growth. In 2019, the share of total GDP contributed by the restricted and services sectors reached 21.1 and 39%, respectively. All this while, the rate of poverty has declined from 29.6% in 2010 to 23.5% in 2019/20. Ethiopia has heavily invested in road and railway infrastructure, industrial parks, universities, and the energy sector over the past decades. It envisions increasing manufacturing's share of the total GDP from the current level of 6.9% to 17.2% by 2030. The plan has also mainstreamed SDGs and climate-resilient green economies in different sectors (**Error! Reference source not found.**).

1.8.8. Key Development Challenges

Ethiopia has seen great improvements in several sectors of its economy (especially in the areas of infrastructure) these past couple of years thanks in part to the great Chinese investment in this part of Africa, and also to the intense government projects aimed at achieving its SDGs of attaining middle income status by 2025. Despite progress in economic growth, sustainability and equitable share of the fruits of economic growth are constrained by many challenges. Yet, about 24% of the population remain poor and the poorest in Ethiopia have become even poorer in the sense that, the high food prices that improves income for many farmers, also makes buying food more challenging for the poorest especially those in the rural areas. In other words, although more farmers are making good incomes from their farm produce, many people in Ethiopia today are unable to afford basic necessities like food due to the high prices.

Frequent severe weather events alongside long-term impacts of climate change undermine agriculture and pastoral livelihoods as well as food security. The incidence of conflict has increased from time to time leading to substantial impacts on lives, livelihoods, and infrastructure. Ethiopia has experienced the worst locust invasion and its effects contribute to threatening the food security and livelihoods of millions of Ethiopians.

Ethiopia has a fledgling private sector, whose growth and job-creation abilities have been hindered by constraints in the business climate and competitiveness. The country's growing workforce (at 2 million per year) puts pressure on absorption capacity of the labour market, necessitates improving current jobs, while creating sufficient new jobs. GDP growth is projected to fall to 5.7% in 2023, driven by industry and by private consumption and investment. A tourism rebound and liberalization of the telecoms sector are expected to boost the growth outlook. Key downside risks to the growth outlook include the civil conflict and debt vulnerabilities. Higher global food and oil prices are expected to increase inflation to the years to come.

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2. CHAPTER TWO: NATIONAL INVENTORY OF ANTHROPOGENIC EMISSIONS AND REMOVALS OF GREENHOUSE GASES

2.1. Introduction

The third Greenhouse Gas (GHG) inventory for Ethiopia is presented in this chapter. In 2015, the second inventory was prepared and included in the Second National Communication (SNC), which was presented to the UNFCCC's eighth Conference of the Parties. The communication contained among others, the second Greenhouse Gas (GHG) inventory compilation of the country with a base year of 1994.

In compliance with the UNFCCC's rules for the development of national communications from non-Annex I Parties (Decision 17/CP.8), the Federal Democratic Republic of Ethiopia has prepared its third national inventory of greenhouse gases. In order to improve decision-making, the GHG inventory was developed with the goals of identifying the main sources and sinks, establishing quantitative estimates of GHG emissions from various sectors, and focusing on emissions and removals within the context of the global contribution to the accumulation of GHG emissions. The compilation took into consideration the GHG inventory in the Second National Communication and used updated guidelines, IPCC inventory software, and databases to produce the inventory both as a duty and to increase technical capability, data/information collecting, and analysis.

The sectors covered are energy, industrial processes and product use (IPPU), agriculture, forestry and land use (AFOLU) and waste. The gases reported from these sectors are: Carbon dioxide (CO_2), Carbon monoxide (CO), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxides (NOX), Sulphur dioxide (SO2) and Non-Methane Volatile Organic Compounds (NMVOC).

2.2. Institutional Arrangements for the Preparation of The Inventory

Ethiopia signed the UNFCCC agreement in 1992 and later ratified on 05 April 1994. As a Party to the Convention, Ethiopia has the obligation under Article 4, Paragraph 1, and Article 12 Paragraph 1 of the Convention to regularly prepare and submit its national communications to the UNFCC. In 2001 and 2015, the country submitted initial national anthropogenic emission inventory communications and its implementation, respectively to the UNFCC. For the purpose of preparing its Third National anthropogenic emission inventory communications and its implementation status, the EPA engaged the Centre for Environmental Sciences, Addis Ababa University with the requisite expertise in environmental science particularly in climate change mitigation and adaptation for conducting scientific inventory of GHG emission in the country. The Third National Communication (TNC) is prepared in compliance and consistent with Ethiopia’s obligations under the Convention. The main objective of the TNC was to prepare, update and communicate the UNFCCC, policies and measures Ethiopia has taken and envisaged to implement in the country.

The Centre for Environmental Sciences, Addis Ababa University, in the process of conducting the inventory and preparation of the third communication report, closely worked with the federal EPA, designated national competent Authority for the implementation of the Convention, and the key climate resilience green economy (CRGE) strategy implementing organizations such as Ministry of Agriculture; Ministry of Industry; Ministry of Mines and Petroleum; Ministry of Transport; Ministry of Urban and Housing Construction; Ministry of Health and Ministry of Water, Irrigation and Energy) as well as other Government departments and institutions. These ministerial offices are accountable for the major GHGs emissions from different sectors such as energy, industrial processes and product use (IPPU), agriculture, forest and other land use (AFOLU), and waste sector. The institutional arrangements being developed and implemented is described Figure 28 below. The consultant, Center for Environmental Science, Addis Ababa University, through provision of capacity building activities such as hands-on training workshops in the overall preparation of the report for line ministries, regions, city administrations, institutes, and agencies. Such efforts have also largely assisted Ethiopia to fulfill its commitment to the UNFCCC by preparing the Third National Communication (TNC) according to the latest IPCC guideline and the UNFCCC reporting requirements.

The overall responsibility of the development and compilation of the GHG Inventory lies with the Federal Environmental Protection Authority. The EPA also ensured that quality checks of the GHG inventory have been completed and that the report meets all international requirements. The responsibility of other government departments and institutions was to provide data and validate the data and information generated by the data they have provided. In terms of quality assurance (QA) and quality control (QC) procedures adopted by the project, the main parties involved were the EPA, the project team, stakeholder partners, experts not directly involved with the work, and government representatives. TNC review and consolidation was done through series of stakeholder platform consultations, external review processes and the project's technical team.

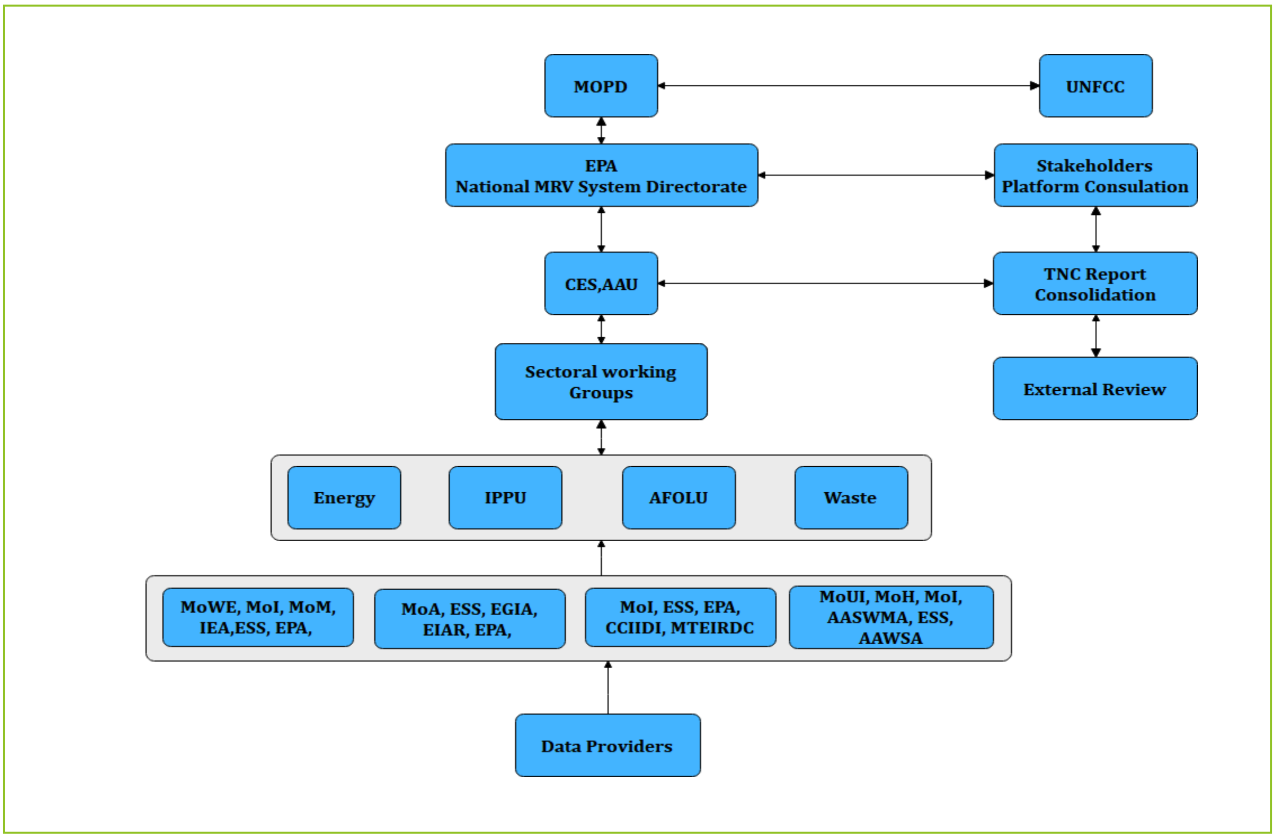

Figure 43 Institutional arrangement only for the preparation of national communication.

2.3. Gaps, Constraints and Needs for National Inventory System

Ethiopia faces several challenges in understanding, mitigating, and adapting climate change, like most developing countries. This section is organized to indicate the constraints and gaps identified during the TNC development process and National Inventory Sytem. The gaps and constraints encountered include:

- Institutional capacity gaps including financial, technological, knowledge and system to handle country wide disaggregated reliable good quality data and information documentation from all sectors of the economy;
- Lack of country specific emission factors (Tier 1 method is mostly used) and the lack of a fully operational information management system related to GHG emission to cater for the steps of compilation.
- The IPCC GHG inventory software was found to be non–flexible to consume nationally available data such as soil classification and categorizes the entire country under one climate zone although the country has diverse agro ecology;
- While the Government has continuously committed to facilitate the identification of relevant environmentally sound technologies and knowledge in most sectors of its economy,

the adoption, diffusion, and application has remained low mainly due to financial constraints, limited capacity and awareness amongst users.

- Ethiopia's ragged topographic features compounded by the uneven distribution of meteorological station was an important challenge for climate change research & systematic observation programs.

- Unstable and continuous government organizational re–structuring compounded by high turnover of trained professional experts. For example, until very recently NMI was agency and now it is institute that is expected to receive more assignments and conduct more research.

- limited technological, institutional capacity to provide timely early warning systems about dangerous hydrometeorological phenomena and climate risk management;

- Limited networking among all stakeholders to play their essential role in tackling the impacts of climate change;

2.4. National Inventory Improvement Plan (NIIP)

The constraints and gaps can be addressed through building the capacity of sector ministries and other institutions and establishing proper and robust information management systems at all levels. Moreover, available, reliable and adaptable technologies for reducing GHG emission along with the following recommendations that should be implemented in tandem with financial support from the Convention's Parties as plan for improvements:

- Build the capacity of the national coordinator of MRV to establish a database management system to ensure the availability of disaggregated reliable good quality data concerning GHG emission and create a platform for exchange of information about who is doing what in relation to climate change mitigation and adaptation;

- Work with the academic institutions to strongly engage in multidisciplinary programs, climate change prediction, adaptation and mitigation research. Include climate change issues in the primary and secondary education curriculum of the country;

- Establish a forum to share outputs of research institutions and other CSOs and NGOs related to climate change observations;

- Address policy related issues to promote technology transfer helpful to address technological needs; Develop standardized approaches to promote formal and informal public climate change awareness and capacity building programs that are adaptable to local conditions and promote the participation of local communities and civil society in MRV.

- Identify, track, and monitor any new potential source of emissions for inclusion in inventories in accordance with IPCC guidelines.

- Develop country specific emission factor key category to improve the quality of the data and move to higher tier.
- The FDRE Environment Protection Authority may give training and instructions to the relevant sector offices on the type of data to be reported along with the necessary details.

2.5. Methodologies and main sources of information

Estimates of GHG emissions provided in this report have been compiled in line with the IPCC 2006 Guidelines for National GHG Inventories and the IPCC Good Practice Guidance (GPG) and Uncertainty Management in National GHG Inventories (IPCC 2000). The purpose of adopting these guidelines and GPG is to ensure that the GHG emission estimates are Transparent, Accurate, Complete, Consistent and Comparable (TACCC).

The estimation of emissions and removal, used a combination of (a) country specific methodology and data (b)IPPC methodology, (c) emission factors (EF)s. The methods were consistent with the IPCC 2006 guidelines for national greenhouse gas inventory (IPPC 2006) and are to the extent possible, in line with international practice. Generally, Tier 1 IPPC methodology were applied, however, there were selected categories such as forestry and livestock (xx for which Tier 2 methodology were used. The methodology has seen some improvement over the previous years. This is as a result of the continuous use

of new and additional country specific activity data. Emission factors were obtained mainly from; (a) facility level plants (b) country specific or regional and international studies and IPCC emission Factor Database(EFDB).Default emission specific factors from the IPCC EFDB were used in many of the categories, however, in case where the country or region-specific emission factor existed, priority was given to it. An overview of the methods and emission factors applied for the calculation of the emissions is presented **Error! Reference source not found.**Selection of the Tier level was guided by the general decision-tree and category specific decision trees provided in the Guidelines. Generally, the selection of the Tier level for all sectors was constrained by the availability of disaggregated activity data (e.g. facility level data) and national emission factors. This led to the adoption of the tier 1 level for all categories estimated except forestry and manure. National activity data was complemented with those available in international databases and default emission factors (EFs) were used. Detailed descriptions of the methods adopted for each sector, including activity data and EFs adopted, are provided in the relevant sections of this report.

Table 24 Mapping methods and emission factors

GHG source & sink category	CO_2		CH_4		N_2O		**HFCs**		**NMVOMs**	
	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
1. Energy	T1	D	T1	D	T1	D	NE	NE	NA	NA
1A. Fuel	T1	D	T1	D	T1	D	NE	NE	NA	NA

combustion										
1.A.1 Energy Industry	T1	D	T1	D	T1	DD	NE	NE	NA	NA
1.A.2 Manufacturing Industries and construction	T1	D	T1	D	T1	D	NE	NE	NA	NA
1.A.3 Transport	T1	D	T1	D	T1	D	NE	NE	NA	NA
1. A. 4. others	T1	D	T1	D	T1	D	NE	NE	NA	NA
1. B Fugitive emissions for fuel	T1	D	T1	D	T1	D	NE	NE	NA	NA
2. IPPU	T1	D								
2.A - Mineral Industry	T1	D								
2.B - Chemical Industry	T1	D	NO	NO	NO	NO	NO	N O	NO	N O
2.D - Non- Energy Products from Fuels and Solvent Use	T1	D	NO	NO	NO	NO	NO	N O	NO	N O
2.F-Product Uses as Substitutes for Ozone Depleting Substances	T1	N O	NO	NO	NO	NO	NO	N O	D	N O
3. AFOLU	T1 &T2	D, CS	T1& T2	D, CS	T1 &T2	D,C S	NO	N O	NO	N O
3.A.1 -Enteric Fermentation	NO	N O	T2,T1	CS, D	NO	NO	NO	N O	NO	N O
3.A.2 - Manure Management (CH_4)	NO	N O	T1	D	T1,T2	CS, D	NO	N O	NO	N O
3.B - Land except Forest land										

	T1	D	NO	NO	NO	NO	NO	N O	NO	N O
3.B.1 - Forest land	T2	CS	NO	NO	NO	NO	NO	N O	NO	N O
3.C - Aggregate sources and non-CO_2 emissions sources on land	T1	D	T1	D	T1	D	NO	N O	NO	N O
3.D - Other	T1	D	NO	NO	NO	NO	NO	N O	NO	N O
4. Waste	T1	D								
4A. Solid waste disposal			T1, CS	D	T1	D				
4B. Biological treatment			T1	D	T1	D				
4C. Incineration and Open Burning	T1	D	T1	D	T1	D				
4D. Wastewater Treatment and Discharge			T1	D	T1, CS	D				

Methods and EF category to use: CS-Country Specific, NE – not estimated, NO- not occurring, D- Default IPPC methodology and emission factor, EF -Emission factory, T1, T2 – Levels of tiers

2.6. Data Sources

The activity data used for this inventory were sourced from a combination of national and international institutions. During data collection, priority was given to data generated within the country. However, in cases where the required data was not available in the country, data from international databases of organizations such as IEA, United Nations, World Bank and FAO were used. Provides an overview of data sources used in the GHG estimation along with the data providers and sources.

Table 25 Activity data and data sources

	Sector/source category	Data type	Data source	Data providers

1. Energy				
	Energy industries	Liquid, solid and biomass consumption dataforelectricity and heat production	Annual reports of ministry of minesand petroleum, and ministryofwaterand energy	EPA, MoM
	Manufacturing industries and construction	Liquid and solid fuels consumption of the country's manufacturing industries and construction	Annual reports from ministry of industry	Ethiopian Environmental Protection Authority
	Transport	Liquid fuels consumption in the transport sector	Annual reports from ministry of transport and logistics	Ethiopian Environmental Protection Authority
	Other sectors	Liquid and biomass fuels consumption datainresidential, commercial / institutional, off-road vehicles, and other machinery	Ministryofwaterand energy and Ministry of urbanization and infrastructure	Ethiopian Environmental Protection Authority
	Fugitive emissions from fuels		Annualreportsfrom ministryof minesand petroleum, and ministryofwaterand energy	Ministry of mines and petroleum and Ethiopian Environmental Protection Authority
2. IPPU				
2.A	Mineral Industry	Industrial production	ESS annualreport	MOI
2.B	Chemical Industry	Industrial production	ESS annualreport	EPA, MOI
2.C	Metal Industry	Industrial production and product type	MOI MRV database, ESS annual report	MTEIRDC
2.D	Non-Energy Products from Fuels and Solvent Use	consumption data and product type	MRV database	MOI
2.F	Product Uses as Substitutes for Ozone Depleting Substances	consumption data and product type	MOI MRV database	MOI
3.AFOLU				
3A	Livestock	Livestock Population and production system	Central Statistical Service	Ministry of Agriculture

3A.2	Manure Management	Manure management systems	MinistryofAgriculture	Ministry of Agriculture
3B	Land	Land use and Land use change	Ethiopian Geo- Information Agency	Ethiopian Geo-Information Agency
3C1	Biomass Burning	Burntareabyland types	Ethiopian Environmental Protection Authority	Ethiopian Environmental Protection Authority
3C2	Lime	Amount of lime	MoA	MoA
3C3	Urea	Amount of urea	EPA	CSS
4.Waste				
4A	Solid waste disposal	Population figures, Waste generation, waste composition, amount and means of waste deposited and various percentage	Ethiopian Statistical services (ESS). UNDP (2018) World Urbanization Prospects; MoUDC (2020) report	Ministry of urban Infrastructure Published international reports.ESS
4B	Biological treatment	Compost	Ministry of Urbanization and Infrastructure	Ethiopian EPA
4C	Incineration and Open Burning	Population Data	UNDP (2018), ESS.	UNDP (2018) Report, ESS.
4D	Wastewater Treatment and Discharge	Population figure, Industrial production, Protein consumption	Total Population data Annual production	UNDP (2018), CSA, MOI, Sugar Corporation, Food, Beverage, and manufacturing services, EEPA

2.7. Quality Assurance (QA) And Quality Control (QC) Procedures

The main purpose of the quality assurance and quality control (QA/QC) plan is to confirm that the inventory is performed with the principles of good practice such as accuracy, comparability, consistency, transparency and completeness. Quality Assurance (QA) is a system of review procedures which conducted by experts not directly engaged in the inventory assessment and compilation process.

Sectorial reference reports were made accessible for public consultation by experts and external technical evaluation as part of the quality assurance (QA) process. The comments, suggestions, recommendations, and observations that followed were noted, addressed, and, where appropriate, taken into consideration. Whereas, Quality Control (QC), on the other hand, is a system of regular tasks used to assess and maintain the inventory's quality while it is being compiled.

2.8. Implementation of Quality Control

The quality control was ensured by checking the correctness of the activity data, parameters, emission factors and calculations.

Table 26 Summary of the QC procedures implemented in the inventory

QC Activity	Procedures	Responsible Party
Check integrity of activity datasource	Ensured that all activity data were sourced from the database of national organizations primarily responsible for preparing and disseminating such information. Ensured adequate documentation and archiving of database.	Inventory compilers
Check for correctness in parameters, units of activity data and conversion factors.	Ensured correct labelling of units in calculation sheets Ensured the correct conversion factors were used during activity data preparation. Checked and documented unusual and unexplained trends noticed for activity data across the timeseries.	Inventory compilers
Check that assumptions and criteria for AD and Emission Factors Selection are documented	Cross-checked AD description for each category, eliminating all possible double counting. Documenting information on estimations for all categories to ensure transparency.	Inventory compilers
Internal consistency	Ensured that the total GHG emissions equaled the sum of the individual emission from the sector and category Ensured that the total GHG emissions equaled the sum of the emission by gas Ensured that the parameters used in multiple categories (e.g. population) were consistent across categories Ensured that the emission data is reported in manner consistent with the calculation tables in the Non-Annex 1 National Communications Reporting Guidelines Ensured that the selection and application of the estimation methods were consistent with IPPC guidelines	Inventory compilers

2.9. Category Level Assessment

Ethiopia's key category assessment under all sectors was performed following the 2006 PC Tier 1 approach. Information on the sector's identified key categories (by level and trend assessment) is presented in and

, for 2018. The categories were ordered in decreasing magnitude and those categories contributing up to about 95 per cent of emissions were selected based on IPCC 2000 Good Practice Guidance. Accordingly, Land Converted to Grassland, Enteric Fermentation, Cropland Remaining Cropland,

Cropland Remaining Cropland, Land Converted to Cropland, Emissions from biomass burning and Other Sectors - Biomass were found a key category emitters and Forest land Remaining Forest land, Land Converted to Forest land and Land Converted to Other land key category sinks for Ethiopian case, contributing 90 per cent.

Table 27 Key Categories Identified on Level Assessment

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2018 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t	Cumulative Total of Column F
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO_2)	124903.9196	124903.9196	0.284711184	0.284711184
3.A.1	Enteric Fermentation	METHANE (CH_4)	82417.56769	82417.56769	0.187866028	0.472577213
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO_2)	55151.93443	55151.93443	0.125715611	0.598292824
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO_2)	-42688.45998	42688.45998	0.09730585	0.695598674
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO_2)	-35956.31321	35956.31321	0.081960314	0.777558988
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO_2)	30376.60684	30376.60684	0.0692417	0.846800688
3.C.1	Emissions from biomass burning	METHANE (CH_4)	11182.64358	11182.64358	0.025490182	0.87229087
1.A.4	Other Sectors - Biomass	METHANE (CH_4)	10614.2575	10614.2575	0.02419458	0.89648545
3.B.6.b	Land Converted to Other land	CARBON DIOXIDE (CO_2)	-9850.435042	9850.435042	0.022453491	0.918938941
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO_2)	6300.277068	6300.277068	0.014361113	0.933300054
3.A.2	Manure Management	NITROUS OXIDE (N_2O)	4722.013272	4722.013272	0.010763553	0.944063607
2.A.1	Cement production	CARBON DIOXIDE (CO_2)	4286.066265	4286.066265	0.009769838	0.953833445
4.D	Wastewater Treatment and Discharge	METHANE (CH_4)	3690.649542	3690.649542	0.00841262	0.962246065

1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CARBON DIOXIDE (CO_2)	3021.65325	3021.65325	0.006887682	0.969133747
3.A.2	Manure Management	METHANE (CH_4)	2515.262661	2515.262661	0.005733394	0.974867141
1.A.1	Energy Industries - Liquid Fuels	CARBON DIOXIDE (CO_2)	1825.8981	1825.8981	0.004162028	0.979029169
1.A.4	Other Sectors - Biomass	NITROUS OXIDE (N_2O)	1681.075812	1681.075812	0.003831914	0.982861083
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N_2O)	1412.515225	1412.515225	0.003219746	0.986080829
1.A.4	Other Sectors - Liquid Fuels	CARBON DIOXIDE (CO_2)	1231.61091	1231.61091	0.002807385	0.988888214
3.B.4.b	Land Converted to Wetlands	CARBON DIOXIDE (CO_2)	983.9469464	983.9469464	0.00224285	0.991131064
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CARBON DIOXIDE (CO_2)	871.32276	871.32276	0.001986129	0.993117193
3.C.6	Indirect N_2O Emissions from manure management	NITROUS OXIDE (N_2O)	818.7135422	818.7135422	0.00186621	0.994983403
3.C.4	Direct N_2O Emissions from managed soils	NITROUS OXIDE (N_2O)	606.3283503	606.3283503	0.00138209	0.996365493
4.A	Solid Waste Disposal	METHANE (CH_4)	415.1697608	415.1697608	0.000946355	0.997311848
3.C.3	Urea application	CARBON DIOXIDE (CO_2)	374.1906667	374.1906667	0.000852946	0.998164794
3.C.5	Indirect N_2O Emissions from managed soils	NITROUS OXIDE (N_2O)	204.8663431	204.8663431	0.000466981	0.998631775

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2018 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t	Cumulative Total of Column F
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO_2)	151.7318102	151.7318102	0.000345864	0.998977638
1.A.3.a	Civil Aviation	CARBON DIOXIDE (CO_2)	136.7795	136.7795	0.000311781	0.999289419
1.A.3.b	Road Transportation	NITROUS OXIDE (N_2O)	97.93855288	97.93855288	0.000223245	0.999512664
4.C	Incineration and Open Burning of Waste	METHANE (CH_4)	96.01516625	96.01516625	0.000218861	0.999731525
4.C	Incineration and Open Burning of Waste	NITROUS OXIDE (N_2O)	18.8613369	18.8613369	4.29933E-05	0.999774519
4.C	Incineration and Open Burning of Waste	CARBON DIOXIDE (CO_2)	16.00293206	16.00293206	3.64777E-05	0.999810996
1.A.1	Energy Industries - Biomass	NITROUS OXIDE (N_2O)	15.280248	15.280248	3.48304E-05	0.999845827
1.A.3.b	Road Transportation	METHANE (CH_4)	13.55591085	13.55591085	3.08999E-05	0.999876727
1.A.1	Energy Industries - Biomass	METHANE (CH_4)	9.61425	9.61425	2.19151E-05	0.999898642
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	NITROUS OXIDE (N_2O)	7.796127	7.796127	1.77708E-05	0.999916413
1.A.1	Energy Industries - Liquid Fuels	NITROUS OXIDE (N_2O)	4.4058108	4.4058108	1.00428E-05	0.999926455
1.A.2	Manufacturing Industries and Construction - Solid Fuels	NITROUS OXIDE (N_2O)	4.1171382	4.1171382	9.38478E-06	0.99993584
2.A.3	Glass Production	CARBON DIOXIDE (CO_2)	3.66793119	3.66793119	8.36083E-06	0.999944201
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH_4)	3.5745125	3.5745125	8.14789E-06	0.999952349
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	METHANE (CH_4)	3.2701875	3.2701875	7.4542E-06	0.999959803
2.A.2	Lime production	CARBON DIOXIDE (CO_2)	3.17125	3.17125	7.22868E-06	0.999967032
4.B	Biological Treatment of Solid Waste	METHANE (CH_4)	3.092	3.092	7.04803E-06	0.99997408

1.A.2	Manufacturing Industries and Construction - Solid Fuels	METHANE (CH_4)	2.30265	2.30265	5.24876E-06	0.999979329
4.B	Biological Treatment of Solid Waste	NITROUS OXIDE (N_2O)	2.2113984	2.2113984	5.04075E-06	0.999984369
1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N_2O)	2.09255898	2.09255898	4.76987E-06	0.999989139
1.A.1	Energy Industries - Liquid Fuels	METHANE (CH_4)	1.848075	1.848075	4.21258E-06	0.999993352
1.A.3.a	Civil Aviation	NITROUS OXIDE (N_2O)	1.140148	1.140148	2.5989E-06	0.999995951
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO_2)	0.630791	0.630791	1.43785E-06	0.999997389
1.B.2.a	Oil	METHANE (CH_4)	0.606467835	0.606467835	1.38241E-06	0.999998771
3.C.2	Liming	CARBON DIOXIDE (CO_2)	0.3069	0.3069	6.99561E-07	0.999999471
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0.202606435	0.202606435	4.6183E-07	0.999999932
1.A.3.a	Civil Aviation	METHANE (CH_4)	0.0239125	0.0239125	5.45071E-08	0.999999987
1.B.2.a	Oil	CARBON DIOXIDE (CO_2)	0.00573513	0.00573513	1.30729E-08	1
1.B.2.a	Oil	NITROUS OXIDE (N_2O)	5.91417E-06	5.91417E-06	1.3481E-11	1
Total						
			261713.52778	438703.94425	1	

2.10. Trend Assessment

When considering the trend assessment (

), the sequence changes somewhat, and the categories whose trend is different from the trend of the overall inventory were identified in level assessment. The Forest land Remaining Forest land become the main key category with about 26.28 % contribution (as carbon sink) to trend, the next five categories of importance are Other Sectors – Biomass 16.11%, Enteric Fermentation 13.61%, Land Converted to Grassland10.17%, Cropland Remaining Cropland 9.89.10% and Emissions from biomass burning 5.06%.

The rest are contributing below 10% of the total GHG emissions. The purpose of the trend assessment is to identify categories that may not be large enough to be identified by the level assessment, but whose trend is significantly different from the trend of the overall inventory and should therefore receive particular attention.

Table 28 Key Categories Identified on Trend Assessment

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2018 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t	Cumulative Total of Column F
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO_2)	124903.9196	124903.9196	0.284711184	0.284711184
3.A.1	Enteric Fermentation	METHANE (CH_4)	82417.56769	82417.56769	0.187866028	0.472577213
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO_2)	55151.93443	55151.93443	0.125715611	0.598292824
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO_2)	-42688.45998	42688.45998	0.09730585	0.69559867

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A	B	C	D	E	F	G
IPCC Category code	**IPCC Category**	**Greenhouse gas**	**2018 Ex,t (Gg CO_2 Eq)**	**|Ex,t| (Gg CO_2 Eq)**	**Lx,t**	**Cumulative Total of Column F**
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO_2)	-35956.31321	35956.31321	0.081960314	0.777558988
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO_2)	30376.60684	30376.60684	0.0692417	0.846800688
3.C.1	Emissions from biomass burning	METHANE (CH_4)	11182.64358	11182.64358	0.025490182	0.87229087
1.A.4	Other Sectors - Biomass	METHANE (CH_4)	10614.2575	10614.2575	0.02419458	0.89648545
3.B.6.b	Land Converted to Other land	CARBON DIOXIDE (CO_2)	-9850.435042	9850.435042	0.022453491	0.918938941
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO_2)	6300.277068	6300.277068	0.014361113	0.933300054
3.A.2	Manure Management	NITROUS OXIDE (N_2O)	4722.013272	4722.013272	0.010763553	0.944063607
2.A.1	Cement production	CARBON DIOXIDE (CO_2)	4286.066265	4286.066265	0.009769838	0.953833445
4.D	Wastewater Treatment and Discharge	METHANE (CH_4)	3690.649542	3690.649542	0.00841262	0.962246065

1.A.2	ManufacturingIndustriesandConstruction-LiquidFuels	CARBON DIOXIDE (CO_2)	3021.65325	3021.65325	0.006887682	0.969133747
3.A.2	Manure Management	METHANE (CH_4)	2515.262661	2515.262661	0.005733394	0.974867141
1.A.1	Energy Industries - Liquid Fuels	CARBON DIOXIDE (CO_2)	1825.8981	1825.8981	0.004162028	0.979029169
1.A.4	Other Sectors - Biomass	NITROUS OXIDE (N_2O)	1681.075812	1681.075812	0.003831914	0.982861083
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N_2O)	1412.515225	1412.515225	0.003219746	0.986080829
1.A.4	Other Sectors - Liquid Fuels	CARBON DIOXIDE (CO_2)	1231.61091	1231.61091	0.002807385	0.988888214
3.B.4.b	Land Converted to Wetlands	CARBON DIOXIDE (CO_2)	983.9469464	983.9469464	0.00224285	0.991131064
1.A.2	ManufacturingIndustriesandConstruction-SolidFuels	CARBON DIOXIDE (CO_2)	871.32276	871.32276	0.001986129	0.993117193
3.C.6	Indirect N_2O Emissions from manure management	NITROUS OXIDE (N_2O)	818.7135422	818.7135422	0.00186621	0.994983403
3.C.4	Direct N_2O Emissions from managed soils	NITROUS OXIDE (N_2O)	606.3283503	606.3283503	0.00138209	0.996365493
4.A	Solid Waste Disposal	METHANE (CH_4)	415.1697608	415.1697608	0.000946355	0.997311848
3.C.3	Urea application	CARBON DIOXIDE (CO_2)	374.1906667	374.1906667	0.000852946	0.998164794

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2018 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t	Cumulative Total of Column F
3.C.5	Indirect N_2O Emissions from managed soils	NITROUS OXIDE (N_2O)	204.8663431	204.8663431	0.000466981	0.998631775
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO_2)	151.7318102	151.7318102	0.000345864	0.998977638
1.A.3.a	Civil Aviation	CARBON DIOXIDE (CO_2)	136.7795	136.7795	0.000311781	0.999289419
1.A.3.b	Road Transportation	NITROUS OXIDE (N_2O)	97.93855288	97.93855288	0.000223245	0.999512664
4.C	Incineration and Open Burning of Waste	METHANE (CH_4)	96.01516625	96.01516625	0.000218861	0.999731525
4.C	Incineration and Open Burning of Waste	NITROUS OXIDE (N_2O)	18.8613369	18.8613369	4.29933E-05	0.999774519
4.C	Incineration and Open Burning of Waste	CARBON DIOXIDE (CO_2)	16.00293206	16.00293206	3.64777E-05	0.999810996
1.A.1	Energy Industries - Biomass	NITROUS OXIDE (N_2O)	15.280248	15.280248	3.48304E-05	0.99984582

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1.A.3.b	Road Transportation	METHANE (CH_4)	13.55591085	13.55591085	3.08999E-05	0.999876727
1.A.1	Energy Industries - Biomass	METHANE (CH_4)	9.61425	9.61425	2.19151E-05	0.999898642
1.A.2	ManufacturingIndustriesandConstruction-LiquidFuels	NITROUS OXIDE (N_2O)	7.796127	7.796127	1.77708E-05	0.999916413
1.A.1	Energy Industries - Liquid Fuels	NITROUS OXIDE (N_2O)	4.4058108	4.4058108	1.00428E-05	0.999926455
1.A.2	ManufacturingIndustriesandConstruction-SolidFuels	NITROUS OXIDE (N_2O)	4.1171382	4.1171382	9.38478E-06	0.99993584
2.A.3	Glass Production	CARBON DIOXIDE (CO_2)	3.66793119	3.66793119	8.36083E-06	0.999944201
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH_4)	3.5745125	3.5745125	8.14789E-06	0.999952349
1.A.2	ManufacturingIndustriesandConstruction-LiquidFuels	METHANE (CH_4)	3.2701875	3.2701875	7.4542E-06	0.999959803
2.A.2	Lime production	CARBON DIOXIDE (CO_2)	3.17125	3.17125	7.22868E-06	0.999967032
4.B	Biological Treatment of Solid Waste	METHANE (CH_4)	3.092	3.092	7.04803E-06	0.99997408
1.A.2	ManufacturingIndustriesandConstruction-SolidFuels	METHANE (CH_4)	2.30265	2.30265	5.24876E-06	0.999979329
4.B	Biological Treatment of Solid Waste	NITROUS OXIDE (N_2O)	2.2113984	2.2113984	5.04075E-06	0.999984369
1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N_2O)	2.09255898	2.09255898	4.76987E-06	0.99998913

						9

A	B	C	D	E	F	G
IPCC Category code	**IPCC Category**	**Greenhouse gas**	**2018 Ex,t (Gg CO_2 Eq)**	**|Ex,t| (Gg CO_2 Eq)**	**Lx,t**	**Cumulative Total of Column F**
1.A.1	Energy Industries - Liquid Fuels	METHANE (CH_4)	1.848075	1.848075	4.21258E-06	0.999993352
1.A.3.a	Civil Aviation	NITROUS OXIDE (N_2O)	1.140148	1.140148	2.5989E-06	0.999995951
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO_2)	0.630791	0.630791	1.43785E-06	0.999997389
1.B.2.a	Oil	METHANE (CH_4)	0.606467835	0.606467835	1.38241E-06	0.999998771
3.C.2	Liming	CARBON DIOXIDE (CO_2)	0.3069	0.3069	6.99561E-07	0.999999471
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0.202606435	0.202606435	4.6183E-07	0.999999932
1.A.3.a	Civil Aviation	METHANE (CH_4)	0.0239125	0.0239125	5.45071E-08	0.99999998

						7
1.B.2.a	Oil	CARBON DIOXIDE (CO_2)	0.00573513	0.00573513	1.30729E-08	1
1.B.2.a	Oil	NITROUS OXIDE (N_2O)	5.91417E-06	5.91417E-06	1.3481E-11	1
Total						
			261713.52778	438703.94425	1	

2.11. Uncertainty Analysis

In order to maximize resource allocation and enhance the quality of the inventory, it is critical to identify the sectors that should be prioritized based on estimates of GHG emission uncertainty. Inventories prepared in accordance with the 2006 IPCC will typically contain a wide range of emission estimates, varying from carefully measured data to highly variable emissions factors. The main activity data used to build the national inventory were obtained from the official annual reports produced by the government institutions. Additional data were also obtained from international reports such as UNDP and World Bank annual reports. However, the activity data used in some cases were not complete, and the methods used to produce the underlying datasets introduced inherent uncertainty into the inventory.

For this inventory, a Tier 2 method for enteric fermentation of major livestock and Forest land as well as a Tier 1 for the rest of the sectors were used as required by the 2006 IPCC Guidelines. Based on the quality of the activity data and the default EFs used, uncertainty levels within the range recommended by the IPCC Guidelines were assigned for the two parameters (AD and EF). The combined uncertainty analysis has been carried out using the tool offered inside the IPCC 2006 software. During the inventory, in most cases the mid value recommended by the IPCC, default EFs used in the IPCC Guideline were adopted for calculating uncertainty. In cases where IPCC recommended a particular methodology, the uncertainty level was derived according to the proposed procedure and used in uncertainty analysis. The trend uncertainty for the individual years of the period 1994 to 2018 varied from 6.9% to 12.7%, while the total inventory uncertainty, for the years 1994 to 2018, ranged from 12.7 % to 20.3%. The uncertainty assessment of the total inventory uncertainty for the year 2018 was 9.7% and trend uncertainty of 12.7%.

Table 29 General Uncertainty (%)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Trend uncertainty	6.9	5.99	6.07	6.2	6.27	6.38	6.5	6.61	6.67	7.5	7.59	6.12
Total inventory uncertainty	20.3	20.5	20.4	20.3	20.27	20.4	20.3	20	20.36	18.03	18.04	12.24

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Trend uncertainty	6.12	8.9	9.34	9.72	9.81	10.27	10.66	11.31	11.76	12.2	12.17	12.7
Total inventory uncertainty	12.59	10.6	10.5	10.4	10.37	10.99	11.18	9.31	9.23	9.17	9.3	9.7

2.12. Assessment of Completeness

To be as thorough as feasible in the coverage, a source category analysis was done to determine the activities in the four IPCC sectors that are accountable for emissions and sinks within the economy. The methodology adopted was according to the *IPCC 2006 Guidelines (IPCC 2007)* with the following notation keys used:

- X= Estimated
- NA= Not Applicable
- NO= Not Occurring
- NE= Not Estimated
- IE= Included Elsewhere

The level of completeness depicting the scope of the inventory is provided in the national and sectoral reporting tables within the respective sections further in this chapter

Table 30 Completeness of the GHG inventory

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO_2 (1)(2)	CH 4	N_2O	HFCs	PFCs	SF6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NOx	C O	NMVOCs	SO 2
Total National Emissions and Removals	X	X	X	X	NA	NA	NA	NA	NE	NE	NE	NE
1 - Energy	X	X	X	NO	NA	NA	NA	NA	NE	NE	NE	NE
1.A - Fuel Combustion Activities	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE

1.A.1 - Energy Industries	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.A.2 - Manufacturing Industries and Construction	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.A.3 - Transport	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.A.4 - Other Sectors	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.A.5 - Non-Specified	NO	NO	NO	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.B - Fugitive emissions from fuels	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.B.1 - Solid Fuels	NO	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.B.2 - Oil and Natural Gas	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.B.3 - Other emissions from Energy Production	NO	NO	NO	NA	NA	NA	NA	NO	NO	NO	NO	NA
1.C - Carbon dioxide Transport and Storage	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.1 - Transport of CO_2	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.2 - Injection and Storage	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.3 - Other	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2 - Industrial Processes and Product Use	x	0	0	x	0	0	NA	NA	NA	NA	NA	NA
2.A - Mineral Industry	X	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.A.1 - Cement production	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.2 - Lime production	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.3 - Glass Production	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.4 - Other Process Uses of Carbonates	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.A.5 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B - Chemical Industry	X	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.1 - Ammonia Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO

Categories	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO_2
2.B.2 - Nitric Acid Production	NA	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.3 - Adipic Acid Production	NA	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	NA	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.5 - Carbide Production	NO	NO	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.6 - Titanium Dioxide Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.7 - Soda Ash Production	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.8 - Petrochemical and Carbon Black Production	NO	NO	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.9 - Fluorochemical Production	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B.10 - Other (Please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C - Metal Industry	X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.1 - Iron and Steel Production	X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.2 - Ferroalloys Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.3 - Aluminium production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.4 - Magnesium production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

2.C.5 - Lead Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.6 - Zinc Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C.7 - Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D - Non-Energy Products from Fuels and Solvent Use	X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D.1 - Lubricant Use	X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D.2 - Paraffin Wax Use	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.D.3 - Solvent Use	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE	NA
2.D.4 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.E.1 - Integrated Circuit or Semiconductor	NA	NA	NA	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.E.2 - TFT Flat Panel Display	NA	NA	NA	NA	NO	NO	NO	NO	NA	NA	NA	NA
2.E.3 - Photovoltaics	NA	NA	NA	NA	NO	NA	NA	NO	NA	NA	NA	NA
2.E.4 - Heat Transfer Fluid	NA	NA	NA	NA	NO	NA	NA	NO	NA	NA	NA	NA
2.E.5 - Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO_2 (1)(2)	CH 4	N_2O	HF	PFCs	SF6	Other halogenate d gases with CO_2 equivalent conversion	Other halogenate d gases without CO_2 equivalent	NO	C O	NMVO	SO 2

				Cs			factors (3)	conversion factors (4)	x		Cs	
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NA	NA	NA	X	NE	NA	NA	NA	NA	NA	NA	NA
2.F.1 - Refrigeration and Air Conditioning	NA	NA	NA	X	NE	NA	NA	NA	NA	NA	NA	NA
2.F.2 - Foam Blowing Agents	NA	NA	NA	X	NE	NA	NA	NA	NA	NA	NA	NA
2.F.3 - Fire Protection	NA	NA	NA	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.4 - Aerosols	NA	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA
2.F.5 - Solvents	NA	NA	NA	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.6 - Other Applications (please specify)	NA	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA	NA
2.G - Other Product Manufacture and Use	NO	NO	NE	NO	NE	NE	NO	NE	NA	NA	NA	NA
2.G.1 - Electrical Equipment	NA	NA	NA	NA	NE	NE	NA	NE	NA	NA	NA	NA
2.G.2 - SF6 and PFCs from Other Product Uses	NA	NA	NA	NA	NE	NE	NA	NE	NA	NA	NA	NA
2.G.3 - N_2O from Product Uses	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.G.4 - Other (Please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.H - Other	NE	NE	NO	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.1 - Pulp and Paper Industry	NE	NE	NA	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.2 - Food and Beverages Industry	NE	NE	NA	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.3 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3 - Agriculture, Forestry, and Other Land Use	X	X	X	NA	NA	NA	NA	NA	NE	NE	NE	NO

3.A - Livestock	0	X	X	NA	NA	NA	NA	NA	NA	NA	NE	NA
3.A.1 - Enteric Fermentation	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.A.2 - Manure Management	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.B - Land	X	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.B.1 - Forest land	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.2 - Cropland	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.3 - Grassland	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.4 - Wetlands	X	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.5 - Settlements	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.6 - Other Land	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO

	Emissions (Gg)			**Emissions CO_2 Equivalents (Gg)**				**Emissions (Gg)**				
Categories	**Net CO_2 (1)(2)**	**CH 4**	**N_2O**	**HFCs**	**PFCs**	**SF6**	**Other halogenated gases with CO_2 equivalent conversion factors (3)**	**Other halogenated gases without CO_2 equivalent conversion factors (4)**	**NOx**	**C O**	**NMVOCs**	**SO 2**
3.C - Aggregate sources and non-CO_2 emissions sources on land	X	X	X	NA	NA	NA	NA	NA	NE	NE	NA	NA
3.C.1 - Emissions from biomass burning	NA	X	NE	NA	NA	NA	NA	NA	NE	NE	0	0
3.C.2 - Liming	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

3.C.3 - Urea application	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.4 - Direct N_2O Emissions from managed soils	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.5 - Indirect N_2O Emissions from managed soils	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.6 - Indirect N_2O Emissions from manure management	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.7 - Rice cultivation	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.8 - Other (please specify)	NA	NO	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.D - Other	NA	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.D.1 - Harvested Wood Products	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.D.2 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
4 - Waste	X	X	X	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A - Solid Waste Disposal	NO	X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.B - Biological Treatment of Solid Waste	NO	X	X	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.C - Incineration and Open Burning of Waste	X	X	X	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.D - Wastewater Treatment and Discharge	NO	X	X	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E - Other (please specify)	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 - Other	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	NA	NO	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
5.B - Other (please specify)	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo Items (5)												
International Bunkers	0	0	0	0	0	0	0	0	0	0	0	0

1.A.3.a.i - International Aviation (International Bunkers)	0	0	0						0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers)	0	0	0						0	0	0	0

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO_2 (1)(2)	CH 4	N_2O	HFCs	PFCs	SF6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NOx	C O	NMVOCs	SO 2
1.A.5.c - Multilateral Operations	0	0	0	0	0	0	0	0	0	0	0	0

2.13. Trends in greenhouse gas emissions

2.13.1. The period 1994 to 2018

Because the removals from the Land category below the emissions from the other categories, Ethiopia continued to be a net GHG source from 1994 to 2018. But, over the course of these 25 years, the net addition of CO_2 grew by 194,862.8 Gg, from 47,559 Gg to 242,421.8 Gg in 2018. The higher removal was from the forestry sector caused by biomass increment in forestland remaining forest land (Table 2.9).

The country saw its emissions rise by 240.46% over the same time period, from 108,333 Gg CO_2-eq to **350,843.9** Gg CO_2-eq. The overall removals from the LAND category grew from 60,774.2Gg CO_2-eq in 1994 to 10,8422 Gg CO_2-eq in 2018.

Table 31 GHG emissions (Gg CO_2-eq) time trend (1994 - 2018)

Year	Total Emissions	AFOLU removals	Net
1994	108333	-60774.2	47559
1995	110981.9	-63880.1	47102
1996	114979.9	-64143.5	50836
1997	120104.3	-63662.8	56442
1998	123121.1	-64175.9	58945
1999	122653.3	-60819.5	61834
2000	126571.1	-64524.3	62047
2001	136204	-68373.1	67831
2002	131478	-72320.9	59157
2003	189254.2	-69376.6	119878
2004	194902.3	-71031.5	123871
2005	185025.6	-72679.6	112346
2006	190749.6	-74346.8	116403
2007	200556.7	-75997.2	124560
2008	254526.6	-71487.8	183039
2009	267073.8	-78422.4	188651
2010	279396	-85296.3	194100
2011	284504.1	-92166.7	192337
2012	300928	-97075.3	203853
2013	312675.6	-102523	210153

2014	320356.3	-103862	216494
2015	332649.3	-104722	227927
2016	343966.5	-105972	237995
2017	352,958.8	-106171	246788
2018	350,843.8	-108422	242,421.8

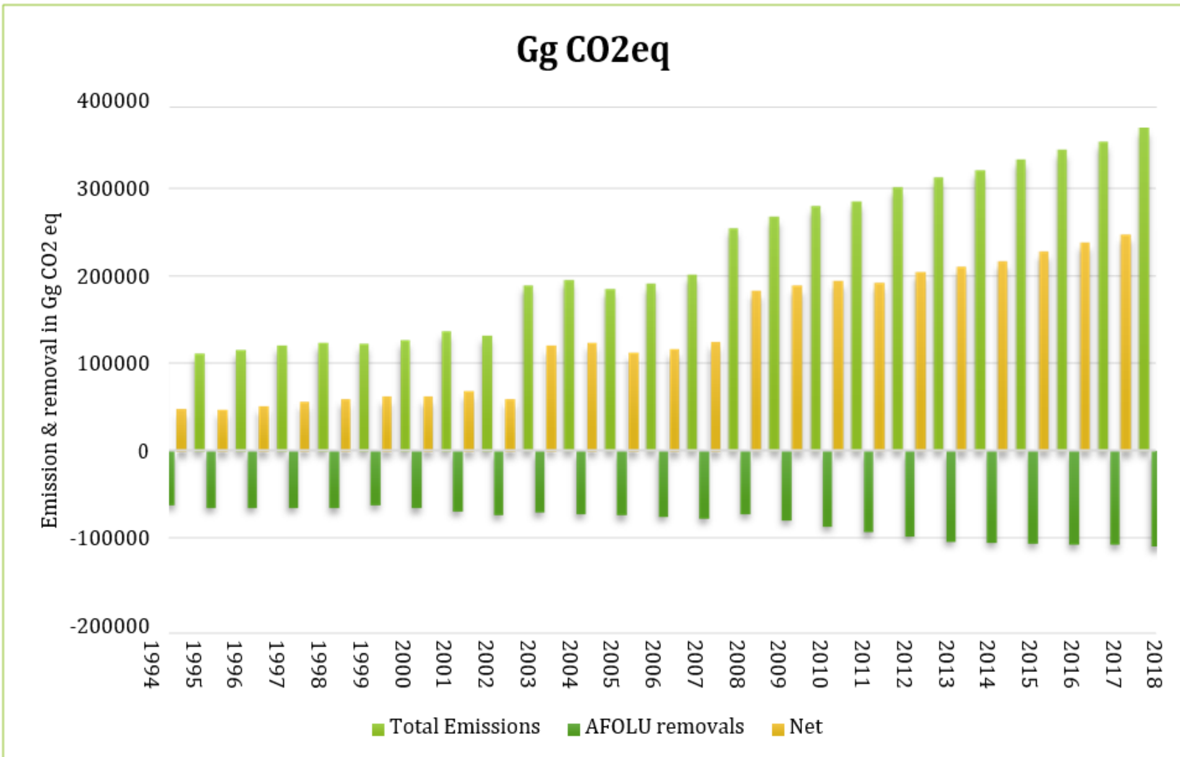

Figure 44 Evolution of national emissions, national removals and the overall (net) situation (Gg CO_2- eq), (1994 - 2018)

The observed increases in the emission trends corresponded to the on-going structural economic transformation agenda which has led to sustained growth and expansion of the national economy. The expansion in the economy has resulted in a notable rise in emissions from road transport, electricity generation from crude-fired thermal plants, increasing demand for biomass use.

Table 32 Summary Table for GHG Emissions in 2018

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	18071.58	3985.11	279.31	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 - Energy	13387.55	425.96	6.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A - Fuel Combustion Activities	13387.54	425.94	6.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1 - Energy Industries	1825.90	0.46	0.07						0.00	0.00	0.00	0.00
1.A.2 - Manufacturing Industries and Construction	3892.98	0.22	0.04						0.00	0.00	0.00	0.00
1.A.3 - Transport	6437.06	0.54	0.33						0.00	0.00	0.00	0.00
1.A.4 - Other Sectors	1231.61	424.71	5.65						0.00	0.00	0.00	0.00
1.B - Fugitive emissions from fuels	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.1 - Solid Fuels	0.00	0.00	0.00						0.00	0.00	0.00	0.00
1.B.2 - Oil and Natural Gas	0.01	0.02	0.00						0.00	0.00	0.00	0.00
1.B.3 - Other emissions from Energy Production	0.00	0.00	0.00						0.00	0.00	0.00	0.00
1.C - Carbon dioxide Transport and Storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2 - Industrial Processes and Product Use	4293.54	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A - Mineral Industry	4292.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.1 - Cement production	4286.07								0.00	0.00	0.00	0.00
2.A.2 - Lime production	3.17								0.00	0.00	0.00	0.00
2.A.3 - Glass Production	3.67								0.00	0.00	0.00	0.00
2.A.4 - Other Process Uses of Carbonates	0.00								0.00	0.00	0.00	0.00
2.A.5 - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
2.B - Chemical Industry	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.7 - Soda Ash Production	0.63								0.00	0.00	0.00	0.00
2.C - Metal Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D - Non-Energy Products from Fuels and Solvent Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.E - Electronics Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.1 - Refrigeration and Air Conditioning				0.20				0.00	0.00	0.00	0.00	0.00
2.G - Other Product Manufacture and Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.H - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 - Agriculture, Forestry, and Other Land Use	374.50	3412.00	268.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A - Livestock	0.00	3412.00	171.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.A.1 - Enteric Fermentation		3296.70							0.00	0.00	0.00	0.00
3.A.2 - Manure Management		115.30	171.74						0.00	0.00	0.00	0.00

3.B - Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.C - Aggregate sources and non-CO_2 emissions sources on land	374.50	0.00	96.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.C.1 - Burning	0.00	0.00	0.00						0.00	0.00	0.00	0.00
3.C.2 - Liming	0.31								0.00	0.00	0.00	0.00
3.C.3 - Urea application	374.19								0.00	0.00	0.00	0.00
3.C.4 - Direct N_2O Emissions from managed soils			71.43						0.00	0.00	0.00	0.00
3.C.5 - Indirect N_2O Emissions from managed soils			0.00						0.00	0.00	0.00	0.00
3.C.6 - Indirect N_2O Emissions from manure management			25.24						0.00	0.00	0.00	0.00
3.D - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 - Waste	16.00	147.15	4.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.A - Solid Waste Disposal		16.61							0.00	0.00	0.00	0.00
4.B - Biological Treatment of Solid Waste		0.12	0.01						0.00	0.00	0.00	0.00
4.C - Incineration and Open Burning of Waste	16.00	3.84	0.06						0.00	0.00	0.00	0.00
4.D - Wastewater Treatment and Discharge		126.58	4.74						0.00	0.00	0.00	0.00
5 - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Memo Items (5)												
International Bunkers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.c - Multilateral Operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2.13.2. Trend of Emissions by Sector

An overview of the greenhouse gas inventories for the period of 1994 to 2018. This table provides a total emission in terms of CO_2 equivalent of the sectors of energy, industrial process and product uses, agriculture, forestry, and other land use and waste.

Table 33 National GHG emissions (Gg, CO_2-eq) by sector (1994 - 2018)

Year	Total Emission	Energy	IPPU	AFOLU	Waste
1994	108333	26207	200.1	80360.23	1565.6
1995	110981.9	26876	263.85	82190.95	1650.7
1996	114979.9	27510	292.71	85486.59	1690.2
1997	120104.3	28434	335.31	89585.36	1749.8
1998	123121.1	28890	337.37	92075.04	1818.6
1999	122653.3	29339	331.44	91106.67	1875.7
2000	126571.1	30070	263.54	94312.22	1925.7
2001	136204	31193	633.46	102357.8	2020
2002	131478	31728	1239.1	96397.36	2113.8
2003	189254.2	32388	603.12	154068.5	2194.1
2004	194902.3	32981	985.3	158659.3	2276.8
2005	185025.6	15549	1162.7	165929.3	2384.3
2006	190749.6	16120	724.85	171419.5	2485
2007	200556.7	16979	702.96	180297.1	2577.8
2008	254526.6	17502	714.95	233617.3	2692
2009	267073.8	17919	687.45	245556.9	2910.1
2010	279396	18293	1145.5	256955.6	3001.7
2011	284504.1	18127	1580.6	261563	3233.8
2012	300928	21601	2805.1	273229.4	3292.1
2013	312675.6	23072	3136.7	283050	3417.1
2014	320356.3	20149	2826.2	293705.5	3675.9
2015	332649.3	22155	3439	303266.6	3788.9
2016	343966.5	22473	3517.7	313569.9	4405.5
2017	352958.8	24389	4017.7	320023.7	4528.4
2018	350,843.9	12516.2	3747.84	329923.034	4656.82

Emissions from the AFOLU sector increased from 80360.23 Gg CO_2 eq in 1994 to 329923.034 Gg CO_2-eq in 2018. The share of GHG emissions from the AFOLU sector out of total national emissions regressed from 74.17% in 1994 to 90.71% in 2018. The major contributor to the GHG emissions during the entire period is the land which is driven by land use change followed by livestock from agriculture, which is driven by the change in number of livestock, poor quality feed and manure management. Energy emissions decreased from 26,207.04 Gg CO_2-eq (24.4%) of national emissions in 1994 to 25,850.52 Gg CO_2-eq (6.9%) in 2018 as depicted in Figure 44.

The contribution of the IPPU sector in total national emissions increased from 200.10 Gg CO_2-eq in 1994 to 3747.84 GgCO_2-eq in 2018 in Figure 44. The very sharp increase in GHG emissions in the IPPU sector is due to the commencement of the production of cement since 2012.

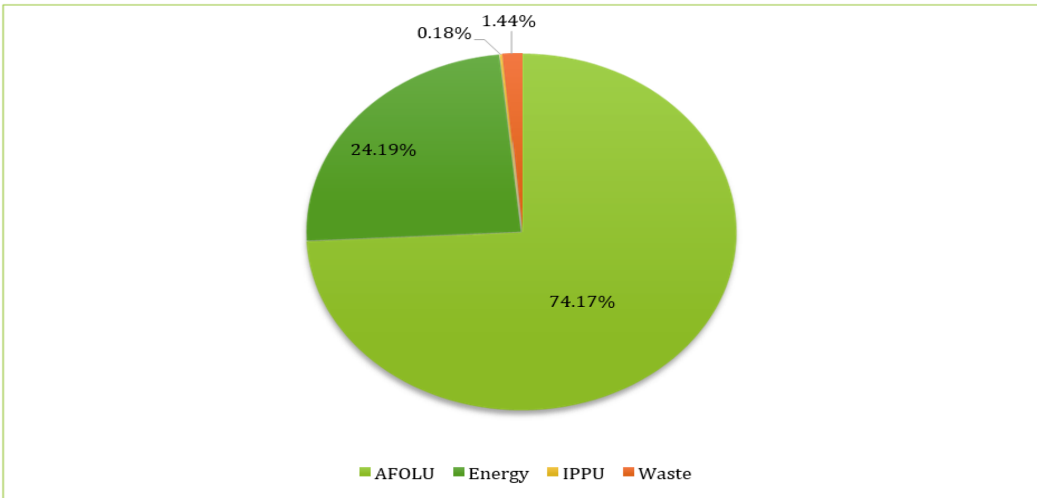

Figure 45 1994 GHG Emissions by Sector

Waste emissions on the other hand varied over this period with the tendency being for a significant increase over time. Emissions from the waste sector increased from the 1994 level of 1565.59 Gg CO_2-eq to 4,656.82Gg CO_2-eq in 2018, representing a 197.45 % increase. In 2018, Energy contributed 6.9 % of emissions, IPPU 1%, AFOLU 90.71% and Waste 1.46% Of total gasses emitted (374,878.3 Gg), CO_2 contributes 50.08%, CH_4 (40.43%), and N_2O (9.49%).

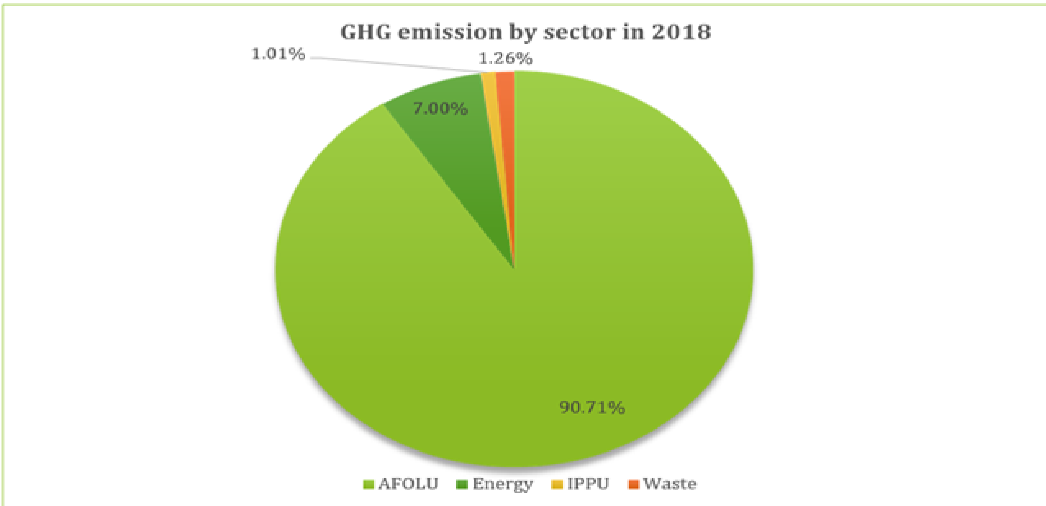

Figure 46 2018 GHG Emissions by Sector

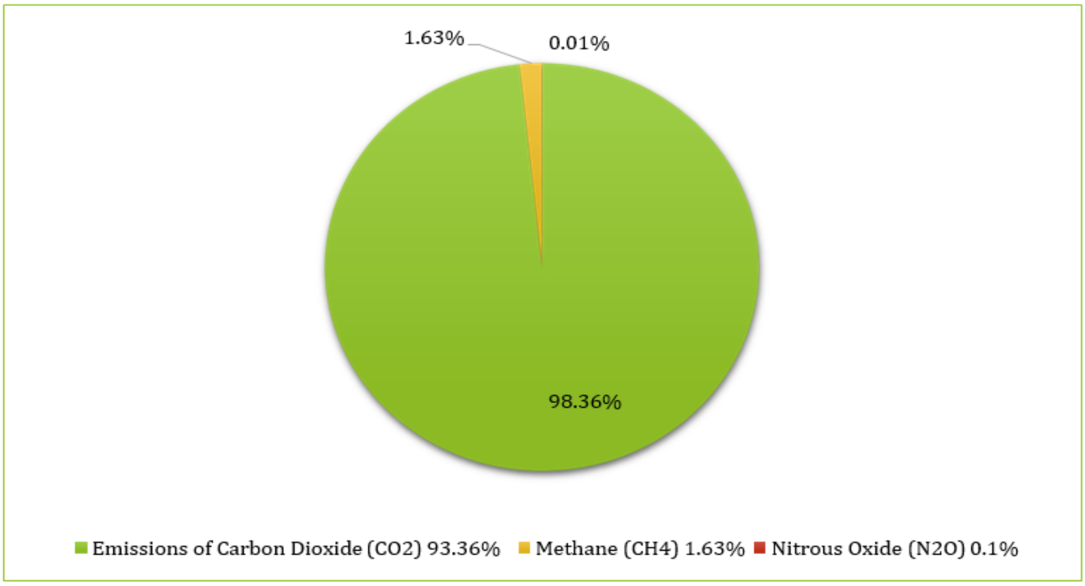

Figure 47 GHG Emissions by gas in 2018

2.14. Energy sector

Most of the economic activities in Ethiopia are largely driven by electricity generated by hydropower and the combustion of liquid and solid fossil fuels. However, combustion usually converts the fossil fuel mainly into carbon dioxide (CO_2), and water (H_2O), and releases the chemical energy inside them as heat. This heat energy is generally either used directly or with some conversion losses to produce mechanical energy that is often used to generate electricity or run engines for transportation. The energy sector is usually the most important area in greenhouse gas emission inventories, and typically contributes over 90% of the CO_2 emissions and 75% of the total greenhouse gas emissions in developed countries. CO_2 accounts typically 95% of energy sector emissions with methane and nitrous oxide responsible for the balance. Literature has shown that stationary combustion is usually responsible for about 70% of the greenhouse gas emissions from the energy sector. About half of these emissions are associated with combustion in energy industries, mainly power plants and refineries. Mobile combustion (road and other traffic) causes about one-quarter of the emissions in the energy sector.

The fuel combustion processes generate heat that is used directly or produces energy to drive mechanical and electrical systems. Through these chemical processes, there is a release of carbon dioxide (CO_2), and other greenhouse gasses (GHGs), GHG precursors, water, and sulfur dioxide (SO2). The extraction of hydrocarbons, oil, and gas also produces GHGs. However, as there are no practical hydrocarbon fuel extraction industries in Ethiopia, the fuel combustion activities in the country are the predominant emissions from the energy sector. The primary contributions come from fuel combustion activities in stationary and mobile applications across several energy sector activities. Moreover, on-site power generation plants, manufacturing industries, power equipment, and commercial and residential activities are among the dominant emission sources in the energy sector.

This Energy GHG inventory covers all the concerning energy activities inventory in the Federal Democratic Republic of Ethiopia, with national-level estimates by the direct GHG emissions of carbon dioxide (CO_2) from the Energy sector. The estimation was done for the years from 2014 to 2018. Moreover, for the sake of consistency in reporting, the estimates for the years 1994 to 2013 have been recalculated to reflect improved activity data or emission factors as appropriately as possible.

2.14.1. Methodological Framework

The Third National Communication (TNC) of Ethiopia is compiled following the UNFCCC guidelines for the preparation of National Communications from parties not included in Annex I to the convention (Decision 17/CP.8). In addition, the IPCC 2006 Guidelines and IPCC software are used to estimate GHG and indirect-GHG emissions by source and removals by sinks in the country for the year 1994-2018.

The 2006 IPCC Guidelines were employed to estimate the National Greenhouse Gas Inventories for fossil fuel combustion activities and fugitive emissions in the energy sector. According to the decision trees provided in Figures, 2.1-2.4 of the guidelines (Vol 2 Energy, Chapter 1, page 1.7) the IPCC Tier 1 Reference and Sectoral Approaches are implemented to estimate the greenhouse gasses emissions.

The Reference or Top-Down Approach

The Reference Approach is a Top-Down method that estimates net GHG emissions from the combustion of primary and secondary fuels supplied to the economy. In this approach, the entire national inventory of fuel supply and data on fuel quantities for each fuel type utilized in the following activities are taken into account:

- production;
- imports;
- exports;
- international bunkers, or the amount of fuel used for international aviation and marine transport;
- stock change or the variations in the quantity of fuel in stock.

The national GHG emissions inventory does not include fuels that are exported or used for international bunkers (i.e., international aviation) since they are deducted from the total apparent consumption. However, as recommended by the IPCC guidelines, the CO_2 emissions from international bunkers are still calculated as a separate memo item.

Calculating the Apparent Fuel Composition

The fuel type data on fuel production, import, export, transport through international bunkers and stock change are used (in kilotons of oil equivalent or gigagrams (Gg)). The data were provided by the Ministry of Water, Irrigation and Energy, the Ministry of Transport

The Reference approach, which is a component in the recommended QA/QC procedures, was used to validate the Sectoral approach for the energy sector and involved the followingsteps:

Estimation of apparent consumption of fuels by type in the country for the inventory years (1994-2018), Conversion of fuel amounts to energy units (TJ), Compute total carbon by multiplying apparent consumption by the respective carbon content of each fuel type, Subtraction of stored carbon (excluded carbon) from fuel carbon and Convert carbon burned to CO_2 emissions.

The Sectoral or Bottom-Up Approach

The sectoral approach is a Bottom-up method for a more accurate estimation of GHGs emissions occurring in each source category from both fuel combustion and fugitive processes. The sectoral approach looks at the actual consumption of the specific sub sectors in the energy sector namely; energy industries (power generation/energy production); transportation; manufacturing industries and construction; and other sectors (residential; commercial, and off-road vehicles, and other machinery). It is moredetailed in the sense that it is applied to each specific end-user category.

Calculating Apparent Fuel Consumption for Each Fuel Type

It is necessary for the energy sectors to use the consumption data, carbon emission factors, and conversion factors for each fuel type (as taken from Tables 1.3 and 1.4 in the 2006 IPCC Guidelines—IPCC, 2007, Volume 2, Chapter 1).

The following variables were necessary to compute the emissions from fuel consumption:

i. The fuel type;
ii. Its consumption figures for every sub-category; and

The carbon emission factors and conversion factors extracted for the fuel type are subdivided into CO_2 and non-CO_2 categories. The Tier 1 approach was used to compute GHG emissions for this inventory where default emission factors were used to estimate emissions since there are no country-specific emissionsdata.The inventory compiler has to state the activity data very clearly as it is advisable to align it with the IPCC inventory software to facilitate data entry in the system

Equation 2.1 from volume 2 of the 2006 IPCC recommendations is used to compute the GHG emissions from stationary combustion.

Emissions GHG, Fuel = Fuel Consumption Fuel * Emission Factor GHG, Fuel

Were,

- Emissions $_{GHG, fuel}$ = emissions of a given GHG by type of fuel (Gg GHG)
- Fuel Consumption $_{fuel}$ = amount of fuel combusted (TJ)
- Emission Factor $_{GHG, fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

The fuel's carbon content is the key determinant of CO_2 emission variables. The carbon content of the fuel and the presumption that the carbon oxidation factor is 1 are both taken into account when calculating CO_2 emission factors, which are expressed in kilograms of CO_2/TJ on a net calorific value basis. Emission factors for CH_4 and N_2O for different source categories differ due to differences in combustion technologies applied in the different source categories. The default factors presented for Tier 1 apply to technologies without emission controls.

During fuel combustion, emissions other than CO_2 are released. Gasses such as methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NOx), carbon monoxide (CO), and non- methane volatile organic compounds are among the non-CO_2 gasses released during the burning of fuels such as coal, gasoline, diesel, wood/wood waste, charcoal, and other biomass fuels(NMVOC).

2.14.2. Emission And Conversion Factors of Different Fuels

The CO_2 emission factors mainly depend on the carbon content of the fuel. Emission factors for CO_2 are in units of kg CO_2/TJ on a net calorific value basis and reflect the carbon content of the fuel and the assumption that the carbon oxidation factor is 1. Emission factors for CH_4 and N_2O for different source categories differ due to differences in combustion technologies applied in the different source categories. The default factors presented for Tier 1 apply to technologies without emission controls. Apart from CO_2, non-CO_2 emissions are emitted during fuel combustion. When coal, gasoline, diesel, wood/wood-waste, charcoal, and other biomass fuels are burnt, the non-CO_2 gasses are emitted. These includes methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC).

The energy sector's default emission factors were obtained from Chapters 2, 3, and 4 of Volume 2 of the 2006 IPCC Guidelines, as well as the Reference Manual (Volume 2) and the refined 2019 guidelines. The default emission factors are used for various fuel types in the estimation of GHGs in energy sector categories. In most cases, we use the average emission factor from IPCC guidelines. Exceptionally, in the transport sector, we used the upper-value emission factor(uncontrolled).

The emission factors for various fuel types produced in various energy industries and various fuel types consumed in energy sector categories are shown in Table 34. Moreover, **Error! Reference source not found.** presents the emission factors used for the three greenhouse gasses namely; CO_2, CH_4, and N_2O, present the calorific conversions, carbon emission factors by fuel, and emission coefficient fraction of carbon oxidized used to estimate the emissions in sectoral and reference approaches.

Table 34 Emission factors used for the energy sector

Energy sector categories			**Emission factors**		
		Fuel type	CO_2	CH_4	**NO_2**
1A1 Energy Industries	Main Electricity and Heat Production	Diesel oil	74100	3	0.6
		Other bituminous coal	94600	1	1.5
	Manufacture of solid fuel and other energy industries	Wood/Wood waste	112000	30	4
1A2 Manufacturing Industries and Construction	Manufacturing Industries and Construction	Motor gasoline	69300	3	0.6
		Other bituminous coal	94600	10	1.5
1A3 Transport	i) Domestic Aviation	Jet kerosene	71500	0.5	2

	ii) Road Transportation	Motor gasoline	73000	33	3.2
		Gas/Deiseal	74100	3.9	3.9
	Commercial/Institutional	Charcoal	112000	200	1
		Natural gas liquids	64200	10	0.6
1A4 Other Sectors	Residential	Wood/Wood waste	112000	300	4
		Liquified petroleum gas (LPG)	63100	5	0.1
	iculture/Forestry/Fishing and Fish farms	Diesel oil	74100	10	0.6
1B Fugitive emissions from fuels	Oil and Natural Gas transport	Natural gas liquid transport (LPG)	0.00043	0.00001	2.2E-9
	ii) Distribution of oil products	Refined product distribution (Gasoline)	2.3E-06	0.00003	-
	iii) Underground mines	Mining	-	18	-
		Post-mining seam gas emission	-	2.5	-
	iv) Surface mines	Mining	-	1.2	-
		Post-mining seam gas emission	-	0.1	-

Table 35 Calorific conversions and carbon emission factors by fuel

Fuel	Calorific values (TJ/1,000 tons)	Carbon emission factor(tC/TJ)
Crude oil	42.08	20.15
Gasoline	44.8	18.9
Jet kerosene	44.59	19.5
Diesel oil	43.33	20.2
LPG	47.31	17.2

Lubricants	40.19	20
Sub-bituminous coal	25.75	26.2
Solid biomass	22.46	29.9
Fuelwood	19.2	29.9
Charcoal	21.1	29.9
Agricultural residues	15.4	29.9

Source: IPCC, 2000, Table 2.4, IPCC, 1996, Energy Reference Manual Tables 1.1 and 1.3.

Table 2.T provides the conversion coefficients for the percentage of carbon oxidized during the combustion of various fuels.

Table 36 Emission coefficients fraction of carbon deoxidized

Fuel	Fraction of carbon oxidized
Coal	26.2
Oil and oilproducts	29.9
Gas (including (LPG)	29.9
Biomass	29.9

Source: IPCC, 1996, Energy Reference Manual, Table 1.6

2.14.3. Fuel Type Used in Energy Sector

Ethiopia predominantly relied on imports of petroleum products to meet its growing demand. The main importing liquid fuels are diesel oil, motor gasoline, liquid petroleum gas, and jet kerosene are some of the energy sources consumed in Ethiopia. The biomass fuels (wood/wood waste and charcoal) and liquified petroleum gas are mainly utilized for cooking, and lighting purposes in the commercials, institutions and residential areas in Ethiopia. Motor gasoline and jet kerosene are mainly used for roads and domestic aviation transportations. Diesel oil is used for off-road vehicles and other machinery applications.

2.14.4. Uncertainty Assessment

The uncertainty analysis has been performed using the tool available within the IPCC 2006 Software. The uncertainty calculated for each fuel type. Generally speaking, methane and nitrous oxide emissions were found to have an uncertainty of over 200 percent, while carbon dioxide emissions were shown to have uncertainty of between 5 and 7.9 percent, which is in agreement with several countries' reports.

2.14.5. Activity Data for Fuel Combustion from Energy Sector

The energy sector activity has been divided into five major categories, namely; energy industries, manufacturing industries and construction, transport, other sectors (residential, commercial/institutional, off-road vehicles, and other machinery), and fugitives' emissions from fuels.

Activity data for the energy sector used in the GHG inventory was obtained from the FDRE Environment Protection Authority (EPA), Ministry of Water and Energy (MoWE), Ministry of Industry (MI), Ministry of Mines (MM), and International Energy Agency (IEA).

2.14.6. Fuel Combustion from the Energy Sector by Fuel Type

Figure 47**Error! Reference source not found.** presents the total fuel combustion from the burning of biomass and various liquid and solid fuel combustions. In Ethiopia, the total fuel combustion shows an increase from 1994 to 2004. However, the consumption of biomass in this subsector remarkably reduced in 2005, by more than half compared to the previous years.

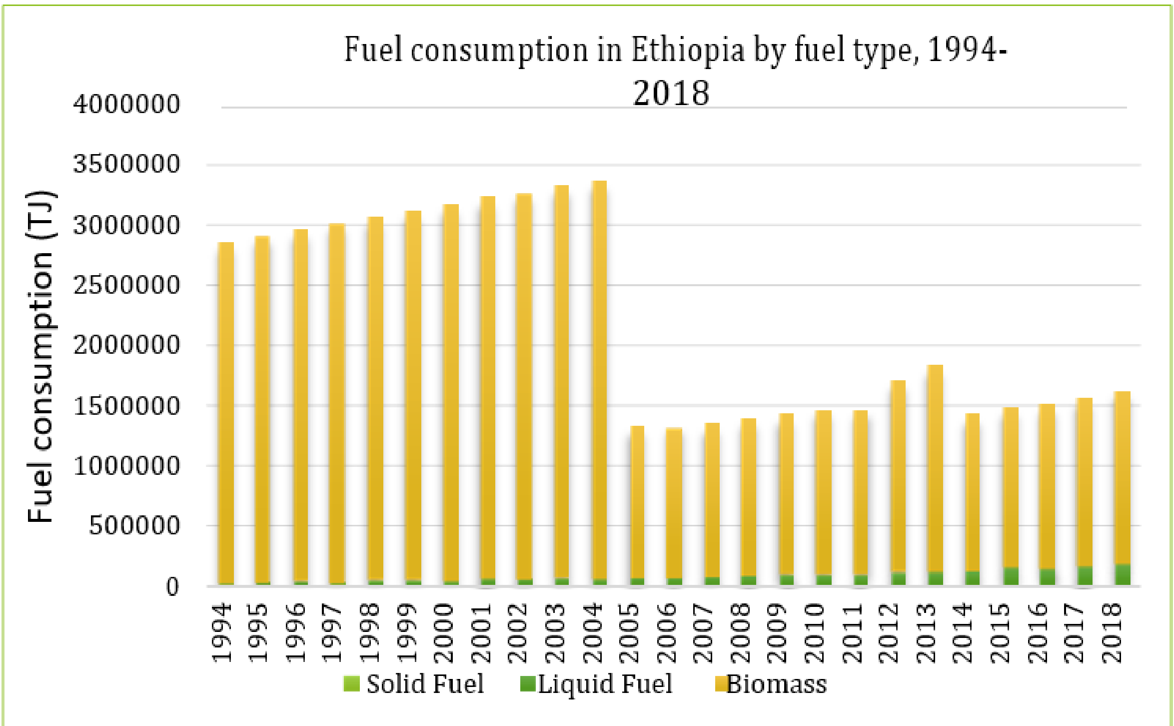

Figure 48 Total fuel combustion (biomass, liquid, and solid fuels) from 1994 to 2018.

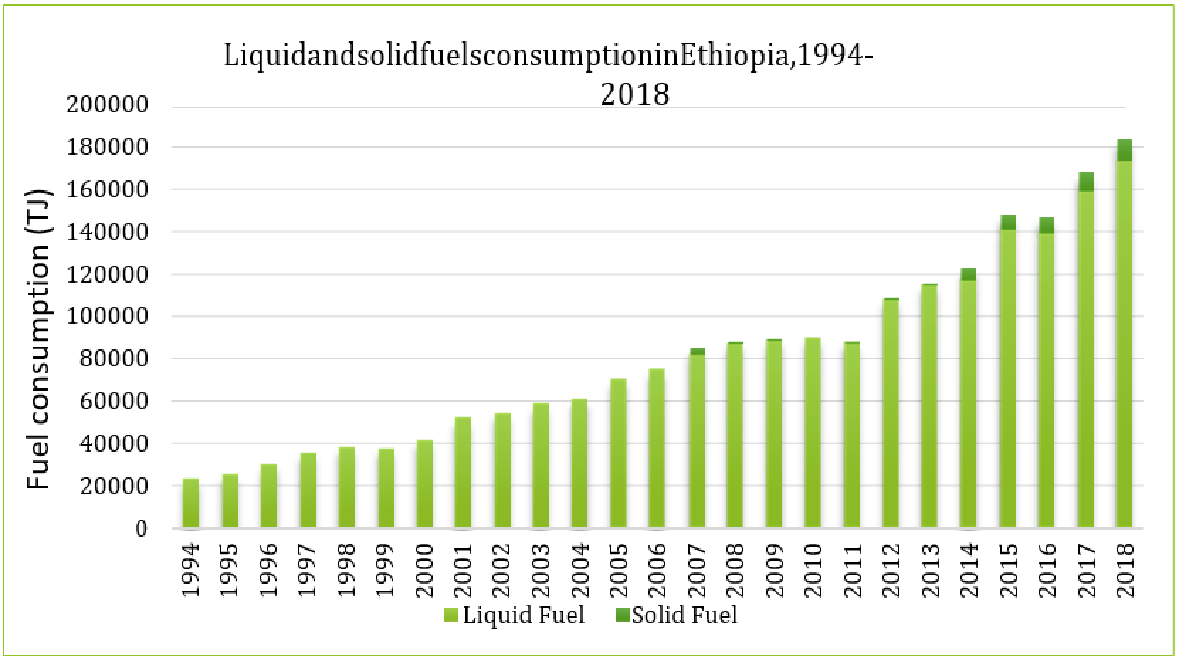

Figure 49 Total fuel consumption of liquid and solid fuels from 1994 to 2018

Ethiopia raised its use of biomass fuels from 2,8 million TJ in 1994 to 3.3 million TJ in 2004. This subsector's fuel usage fell sharply to 1.2 million TJ in 2005 mostly due to a decrease in biomass fuel used for lighting and cooking in towns and cities as a result of increased electric power supply and the growth of condominium housing in the country. However, as shown in Figure 48, the consumption of liquid fuels in Ethiopia increased from 1994 to 2018 mainly due to an increase in the number of vehicles and manufacturing industries in the country. Moreover, solid fuel consumption increased from 2007 to 2018. The transport sector consumes the largest share of the imported liquid fuel followed by manufacturing industries and construction

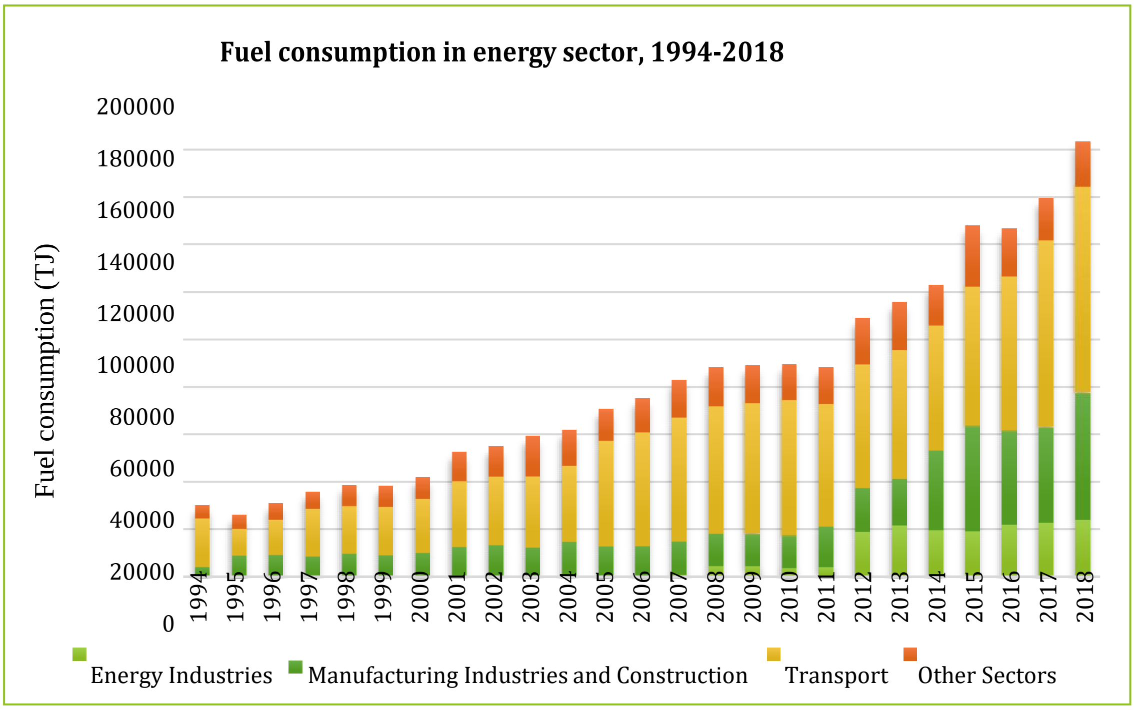

Figure 50 Total fuel consumption from the energy sector (1994 to 2018)

2.14.7. Fuel Combustion Activities by Sub-Sector

The energy sector mainly comprises exploration and exploitation of primary energy sources; conversion of primary energy sources into more use-able energy forms in refineries and power plants; transmission and distribution of fuels; use of fuels in stationary and mobile applications. Emissions arise from these activities by combustion and as fugitive emissions or escape without combustion. For inventory purposes, fuel combustion may be defined as the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus. This definition aims to separate the combustion of fuels for distinct and productive energy use from the heat released from the use of hydrocarbons in chemical reactions in industrial processes, or the use of hydrocarbons as industrial products. There are cases where demarcation with the industrial processes and product use (IPPU) sector is needed.

The following principle has been adopted for this: Combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs. These source

categories are normally 2B and 2C. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of the Energy Sector source categories (normally 1A1 or 1A2). Typically, only a few percent of the emissions in the energy sector arise as fugitive emissions from extraction, transformation, and transportation of primary energy carriers. Fuel combustion activities mainly comprise; Energy industry (1A1), Manufacturing industry and Construction (1A2), Transport (1A3), Other sectors (commercial, residential, agriculture) (1A4), and Fugitive emissions from fuels (1B) are considered as fuel combustion activities.

2.14.8. Fuel consumption by Energy Industries Sub-sector

This sub-chapter highlights Ethiopia's energy supply from energy industries sub sectors. The methodology and procedures used in preparing this inventory were drawn from the IPCC's 1996 Guidelines for National Greenhouse Gas Inventories, it's Good Practice Guidance (GPG) for 2000 and 2003, and its 2006 guidelines. The base year for this inventory process was 1994 and activity data for all years up to 2018 were collected and applied in the development of the inventory. The energy consumption for energy industries sub sector includes electricity generation, and other energy industries. Most energy industries in Ethiopia use diesel oil as a fuel to generate heat and electricity. The consumption of diesel oil in this sub sector showed an increase by two orders of magnitude from 346 TJ in 1994 to 24,641TJ in 2018 from liquid fuels.

During the inventory years (1994-2018), total energy consumption in the country has increased from 3596TJ in 1994 to 12819 TJ in 2018 from biomass. The energy consumption of liquid fuels for electricity generation is relatively lower from 1994-2011 (Fig. 2.10) and the majority of energy supplies was consumed from biomass. From 2007 to 2018, liquid fuel consumption for electricity generation exponentially increased probably due to the booming of industrial parks and small-scale industries in Ethiopia (UN Industrial Development organization, 2018). On the other hand, biomass consumption for other industries was the dominant energy source for the energy industry in the period from 1994 to 2011 as shown from Figure 2.10. Traditional biomass, including firewood, charcoal, and agro-residue fuels are the main source of energy sources and it accounts for 91.2% of energy consumption (3596 TJ) in 1994, but decreased to 34% of energy consumption from the total energy consumption in 2018, due to the fuel type transition from biomass to liquid fuels.

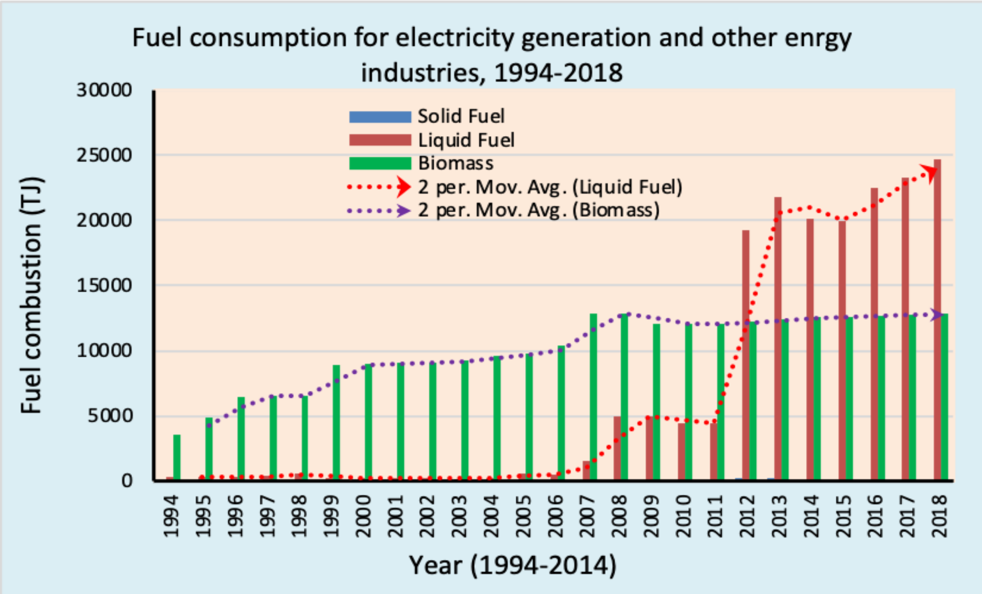

Figure 51 Energy consumption of liquid fuels and biomass in the energy industry from 1994-2018

Energy supply from solid fuels contributes 0.1%, which is insignificant compared with energy supply from liquid fuels and biomass in energy industries.

2.14.9. Fuel Consumption by Manufacturing Industries and Construction Sub-sector

The manufacturing industry in Ethiopia has been initiated since the late 1950's when a series of five-year development plans were launched (Gebreeyesus, M., 2016). The expansion activities of this industrial sector have been increasing throughout much of the 1960s and early 1970s. The sector encouraged agro-industrial activities by substituting domestically produced goods for imported items. Ethiopia is known as an agrarian country and the industrial economic sector in general and manufacturing, in particular, have been growing very slowly for several decades. The contributions of industries to national GDP are small. Currently, the government of Ethiopia is pursuing a strategy to expand the country's manufacturing sector. For developing countries like Ethiopia, growth in export-oriented manufacturing is vital for sustaining economic expansion that could drive inclusive growth for a growing population. Moreover, the growth in export base manufacturing could help to enhance further economic opportunities in the country. The manufacturing industry in Ethiopia consumes fossil fuels in both liquid and solid forms. Liquid fuel was the dominant energy source in the year 1994 to 2006. However, the manufacturing sector started using solid fuels in 2007. This could be related to the formulated comprehensive industrial development strategy that was launched in 2002/03. The Ethiopian government has been planning to expand its cement industry and, currently, the number of cement plants in the country has reached 20 (Mulatu et al., 2018). As the primary fuel used in the cement industry is coal, a rise in solid fuel consumption in the country could potentially be related to the expansion in the cement industry.

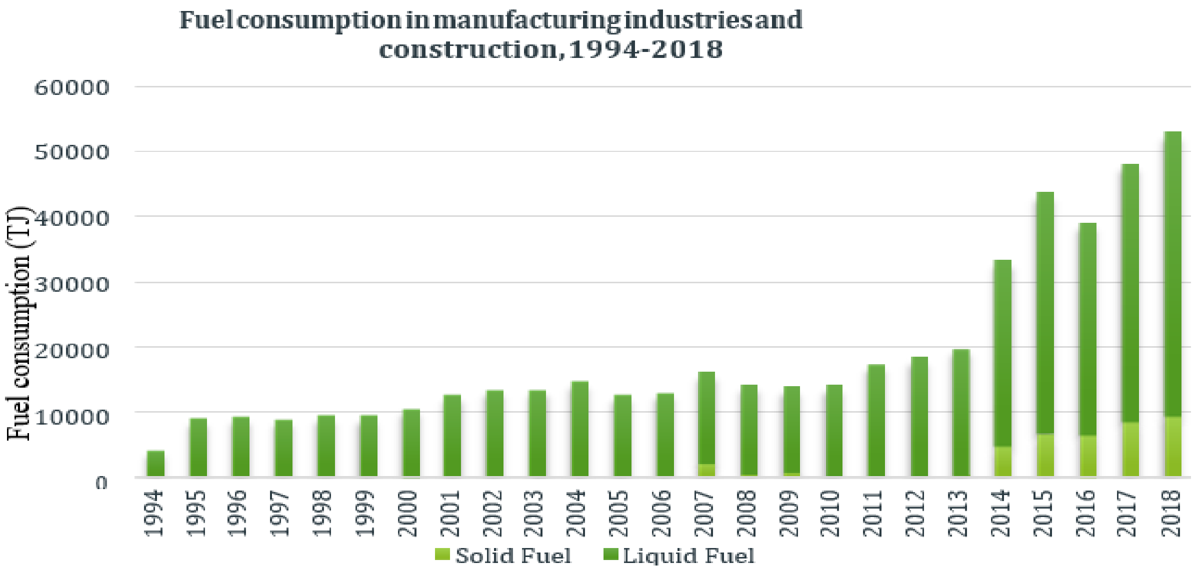

Figure 52 Amount of fuel consumption from the Manufacturing sector from 1994 to 2018:

The transport sub-sector plays a vital role in the combustion of liquid fuels and contributes significantly to the economic developments in Ethiopia. The importance of the transport services sector in the Ethiopian economy has grown considerably in recent years. Efficient transport services and infrastructure are vital to exploiting the economic strengths of all regions of Ethiopia, to supporting the internal market and growth, and to enabling economic and social cohesion. Ethiopia has 10% registered average growth rate of car ownership until 2018 (Kassahun, 2018), indicating the number of registered vehicles in Ethiopia is exponentially increasing. The main energy consumptions reported in the transport sub-sector includes fuel combustion in domestic civil aviation, road transportations which comprise energy consumed by cars and trucks. Diesel oil is the primary liquid fuel used for track transportation in Ethiopia. The time trend of diesel oil consumption is increasing from 5808 TJ in 1994 to 78362 TJ in 2018, increasing by 1249% of diesel oil. This is due to the fact that Ethiopia is the land locked country in East Africa and has 90% of its freight transportation both in the import and export sector (Yonas, 2019), indicating high amount of diesel oil consumption by light and heavy-duty trucks in Ethiopia.

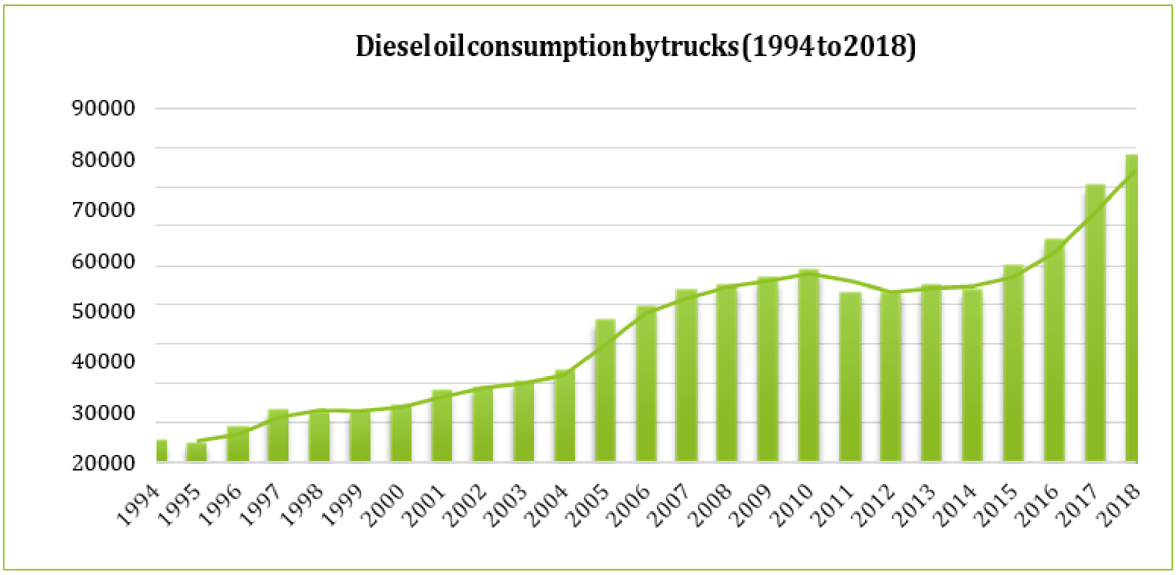

Figure 53 Diesel oil consumption by trucks per year from 1994-2018

The gasoline consumption by cars in Ethiopia has increased from 4309 TJ in 1996 to 8222 TJ (the highest amount of gasoline consumption in Ethiopia) in 2002, indicating that the number of private car ownership is increasing. From 2003 the gasoline consumption in Ethiopia started to decline to 7123 TJ in 2018. This is probably due to the intervention of more public transportations like light rail transits, new meter taxis, new school buses, new double deck buses and dew euro 111 buses (Kassahun, 2018). This shows that the private car ownership declines and new public transportations is introduced, hence the consumption of gasoline by cars insignificantly changes for almost 10 years from 2009 to 2018 as shown

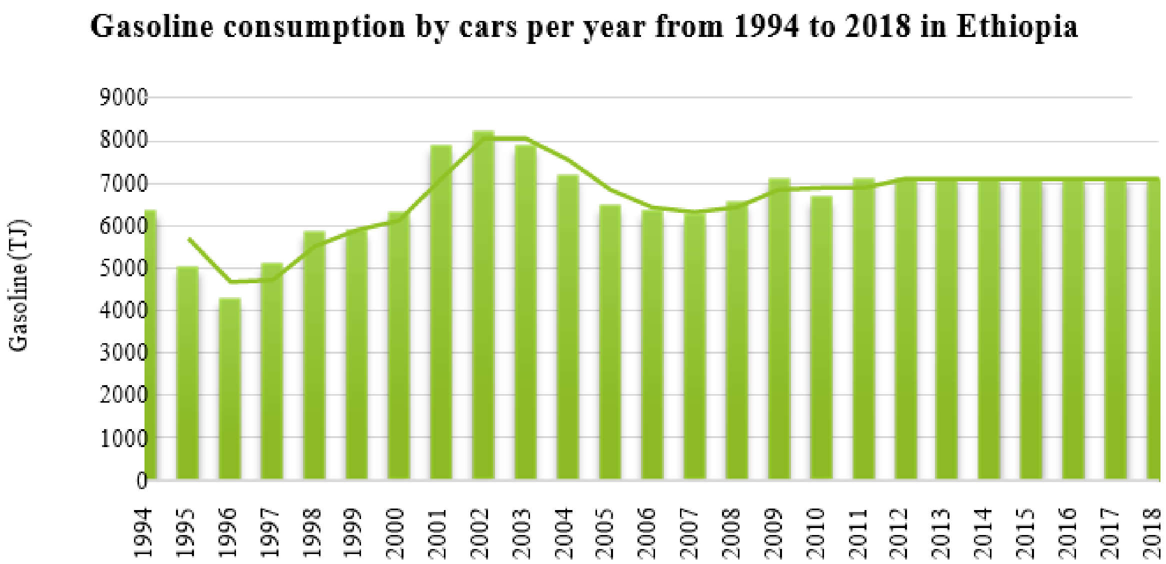

Figure 54 Total gasoline consumption by cars per year from 1994 to 2018

The time trend of consumption of jet kerosene for domestic aviation is slightly increasing from 1124 TJ in 1995 to 1913 TJ in 2018, which increased by 70% from that of kerosene consumption in 1995 as shown from

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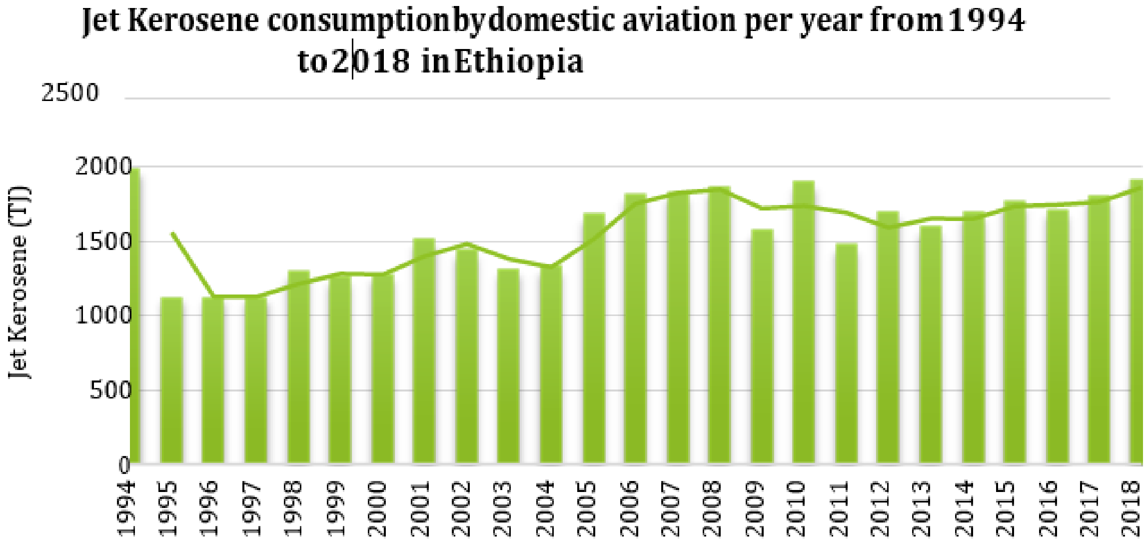


Figure 55 Jet Kerosene consumption of domestic aviation per year from 1994 to 2018.

This is due an increasing number of aircrafts 35 in 207 to 108 in 2018 with 22 domestic destinations in Ethiopia, indicating the increasing consumption of jet kerosene in Ethiopia (Ethiopia Airlines, 2019). In general, the transport sub-sector includes fuel combustion in civil aviation, road transportation, and railways. Road transport comprises motorcycles, passenger cars, as well as light- and heavy-duty trucks. The transport sub sector consumes the majority of the imported liquid fuels in Ethiopia. Motor gasoline is the primary liquid fuel used for transportation in Ethiopia. In Ethiopia, the transport sub sector consumed 14,173.71 TJ of liquid fuels in 1994 which considerably increased to 85,485.4 TJ in 2018). As the 2006 IPCC guidelines outlined, the fuel consumption by other sectors includes consumption in residential, commercial/institutional, off-road vehicles, and other machinery. Relevant activity data on fuel consumption in the other sectors are obtained from EPA databases and are presented in as shown in the prevailing fuel type in this sector is biomass which includes wood, wood waste, and charcoal burning for cooking and lighting purposes.

As shown in the consumption of biomass fuels in Ethiopia increased from 2824410.1 in 1994 to 3291398.8 TJ in 2004. However, in 2005 fuel consumption in this subsector suddenly dropped to 1234282.8 TJ. Likewise, the greenhouse gas emission in this sub sector significantly increased from 1994 to 2005. Starting from 2005, the biomass fuel consumption in this subsector significantly dropped compared to the previous years, nearly declining by 60 percent relative to 2004. The reduction of biomass uses for cooking, lighting, and heating may be mostly attributed to the rise of condominium housing in cities and towns as well as the use of electric cooking stoves, improved cooking stoves, and gas cylinders increased in residences, businesses, and institutions. Also shows that the fuel consumption from the year 2005 to 2018 is more or less constant. The amount of fuel consumed between 2005 and 2018 are nearly steady, with some exceptions, remarkably increased in the years 2012 and 2013, and decreased in 2014.

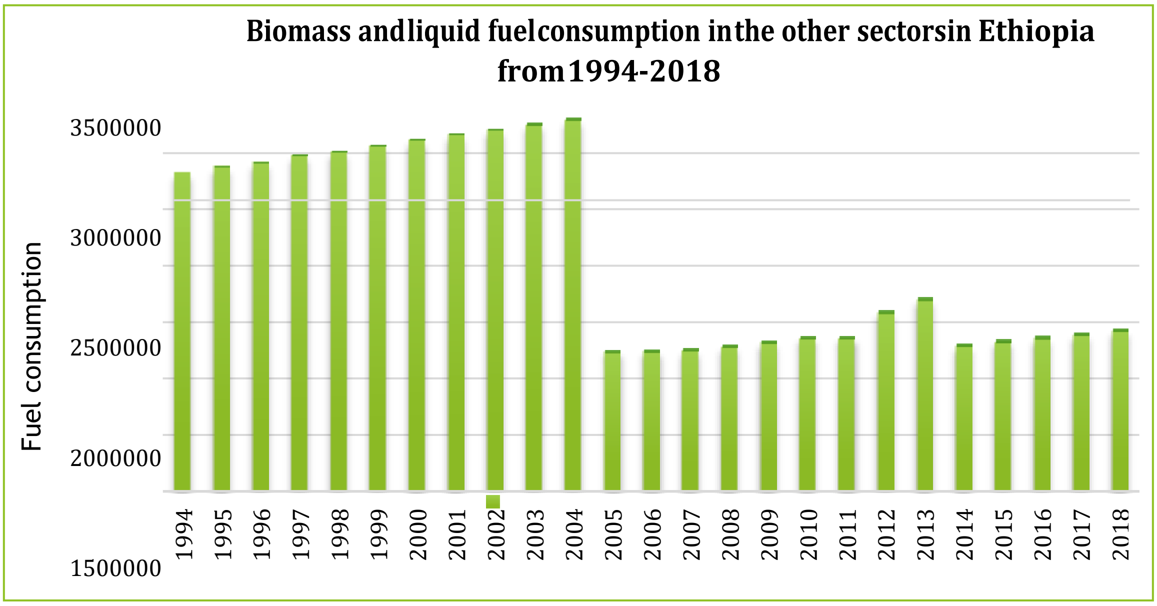


Figure 56 Fuel consumption in other sectors (commercial/institutional and residential activities) from 1994 to 2018

hasshownthattheliquidfuelconsumptionintheothersectorsinEthiopiahas been gradually increasing from the year 1994 to 2018. also shows a slight increaseinfuelconsumptionfor this subsector between 2005 to 2013 until it decreased in 2014 remarkably. Moreover, a slight increase in fuel consumption was also observed again continuing from 2014 to 2018. This is due to the increase in fuel consumption for small-scale generators in commercial centers, shops, and residential. In Ethiopia, frequent power cuts are a major problem in all areas of the country that are connected to electricity, and many households have backup power supplies for lighting and cooking, with the use of diesel generators, increasing liquid fuel consumption (Beyeneetal,2018).

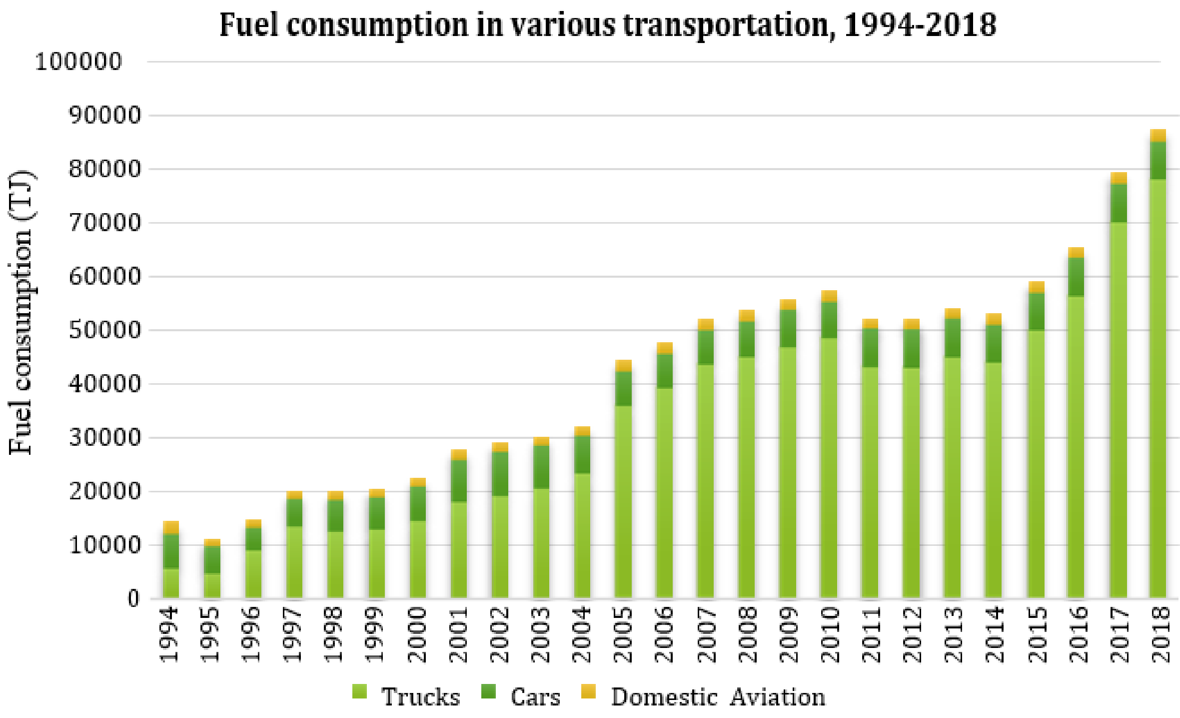


Figure 57 Liquid fuel consumption in the other sectors (residential, off-road vehicles, and other machinery) from 1994 to 2018

From the total liquid consumption by other sectors, the majority of liquid fuel was consumed by residents compared to the off-road vehicles and machinery for agriculture applications as shown in Figure 2.18. The total liquid fuel consumption by residential was 3431 TJ in 1994, while the liquid fuel consumption by off-road vehicles and other machinery was 1204 TJ in the same year. Likewise, the total liquid fuel consumption by the off-road vehicles and other machinery was 7310 TJ in 2018 while the total liquid fuel consumption by residential vehicles was slightly increased to 7784TJ in the same year.

The general trend for liquid fuel consumption increased from 3431TJ in 1994 to 18070 TJ in 2015, which increased by 427% of liquid fuel consumption by the residential (). This is because the intermittence of electricity from the national grid causes the increased consumption of liquid fuels for lighting, and cooking in the residential. However, the consumption of liquid fuels decreased from 18070TJ in 2015 to 7784TJ in 2018, probably due to the increase of off-grid small-scale solar energy for lighting and cooking in Ethiopia.

2.14.10. GHG Emissions of Energy Sector

2.14.11. Emissions by gastype Carbon dioxide (CO_2) emissions from the energy sector

As shown in , the total combined CO_2 emissions from liquid and solid fuel burninginthe energy sector increased from 2092.0025 Gg CO_2-eq in 1994 to 13301.3431 Gg CO_2-eq in 2018. The CO_2 emission from the transport sector contributes nearly half of the total CO_2 emission in the energy sector. The manufacturing industries and construction take the second level which is followed by the energy industries. Other sectors' contribution to the total CO_2 emission in Ethiopia is the lowest.

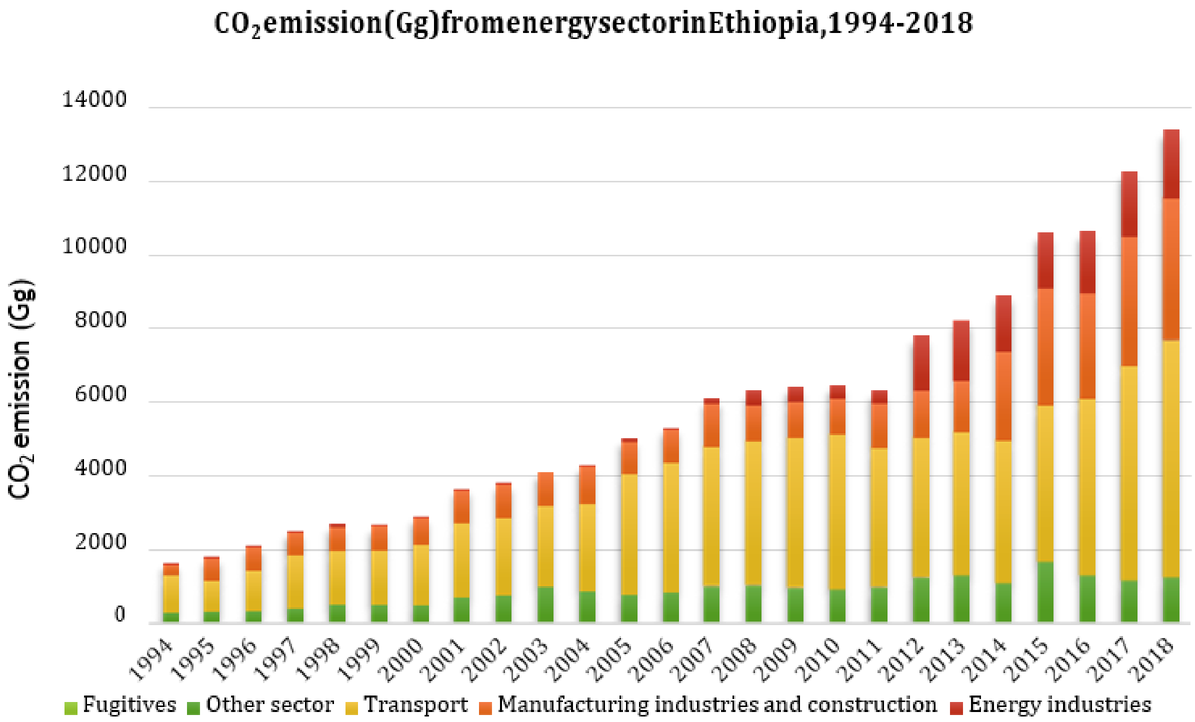


Figure 58 Combined CO2 emissions by sector from liquid and solid fuel combustions from 1994-201

As shown in Figure 57 the total CO_2 emission from liquid and solid fuels increased from 1632.9695 in 1994 to 12516.2188 Gg in 2018.

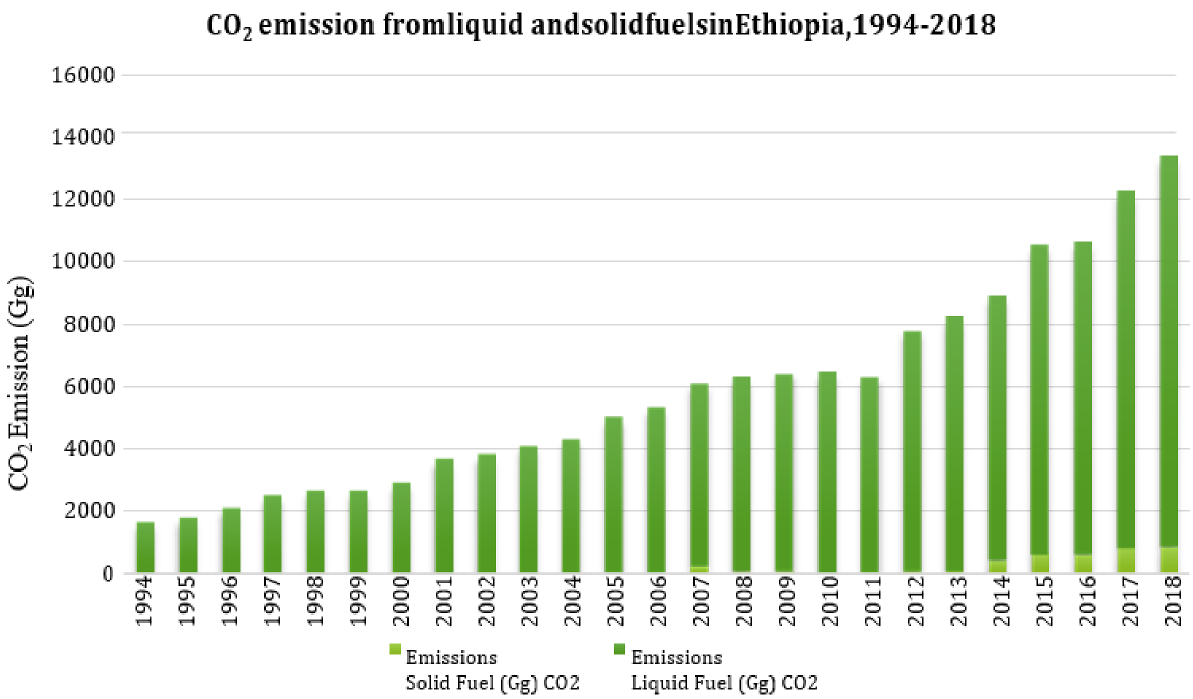


Figure 59 Combined CO2 emissions from liquid and solid fuel combustion from 1994-2018

2.14.12. Methane (CH_4) emissions from the energy sector

Methane emissions occur from incomplete fuel combustion of hydrocarbons. The amount of CH_4 released also depends on the fuel's methane content, the number of unburned hydrocarbons in the engine, the type of engine, and any post-combustion restrictions (IPCC, 1997, Volume 3, Chapter 1, p. 34). At the national level, the CH_4 emissions from the combustion of fossil-based fuels are relatively negligible, but the uncertainty is high. Figure 59 presents the total aggregated methane (CH_4) emissions from the energy sector. The lowest and highest methane emissions were recorded in the years 2005 and 2004 with measurements of 9068.4024 Gg CO_2-eq and 24692.9817 Gg CO_2-eq, respectively.

2.14.13. Nitrous oxide (N_2O) emissions from energy sector

Error! Reference source not found. The nitrous oxide emission substantially decreased from 3960.2320 Gg (CO_2-eq) in 2004 to 1451.6832 Gg (CO_2-eq) in 2005. It shows gradual increments in three periods, 1994- 2004, 2005-2013, and 2014-2018. The other sectors (residential, commercial, and institutional)contributealion'sshareofnitrousoxidegasemissionsintheenergy sector in Ethiopia, 1994-2018. The aggregated nitrous oxide emission increased from 11.3748 Gg CO_2-eq in 1994 to 13.3111 Gg CO_2-eq in 2004 however in 2005 it reduced to 4.8852 Gg CO_2-eq.

2.14.14. Comparison of GHGs emissions from the energy sector in 2013 and 2018

presents the comparison of the share of CO_2 emissions from the energy sector in 2013 and 2018. The dominant sub-sector in the energy sector for carbon dioxide emission is the transport sector with 47 and 48% in 2013 and 2018, respectively. Manufacturing industries and construction growth from 17% (2013) to 29% (2018) whereas both the energy industries and other sectors' contribution to total CO_2 emission reduced from 20% and 16% (2013) to 14% and 9% (2018), respectively.

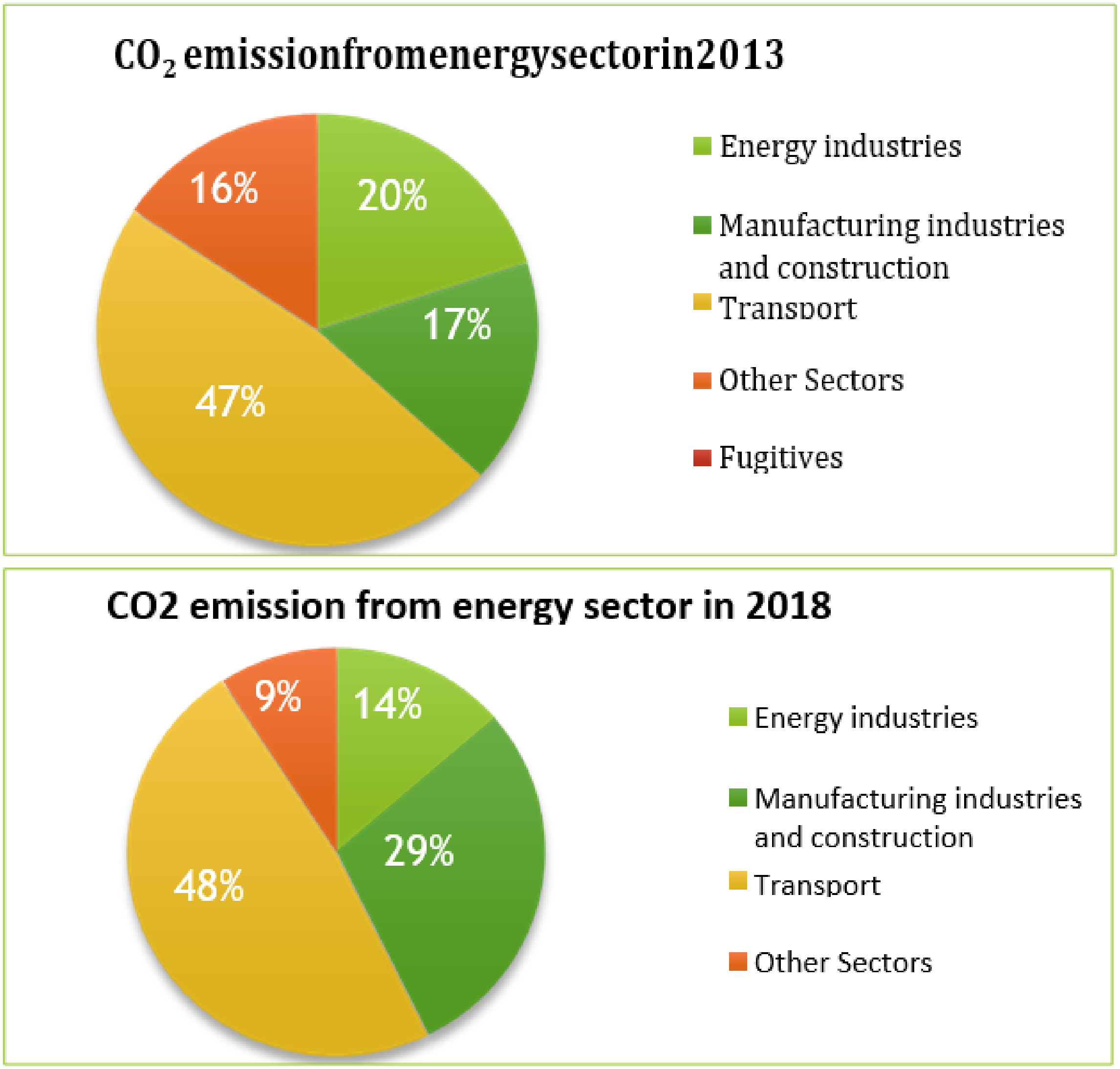


Figure 60 The share of CO2 emission within the energy sector in 2013 and 2018

Figure 2-61: CH_4 emission in the energy sector mainly dominated by other sectors (residential, commercial/institutional, off-road vehicles, and other machinery), 2013 and 2018

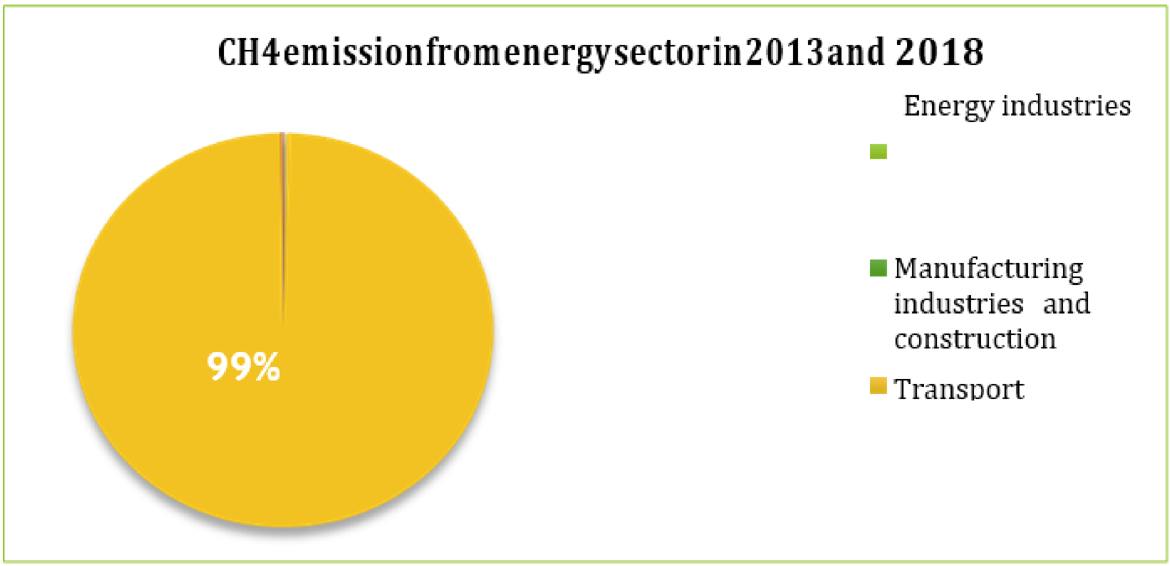
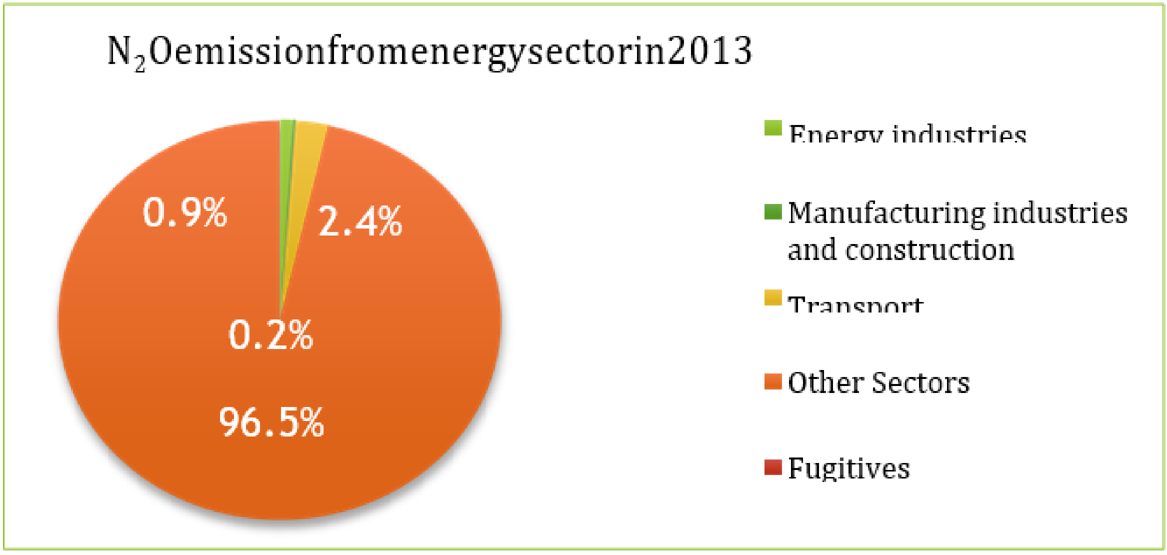


Figure 62 CH4 emission in the energy sector mainly dominated by other sectors (residential, commercial/institutional, off-road vehicles, and other machinery), 2013 and 2018

Figure 62 present the share of CH4 and N2O gas emissions from various energy sectors in 2018. The other sectors (i.e., commercial/institutional and residential subsectors) contributed the lion-share of methane emissions in Ethiopia with a percentage of 94% which is followed by transport with 6% in 2018.] The aggregated nitrous oxide e emissions from various energy sectors in 2018. Likewise, the other sectors (i.e., commercial/institutional and residential subsectors) contributed the lion-share of nitrous oxide emissions in Ethiopia with a percentage of 96.5% which is followed by the transport and manufacturing industries and construction with 2.4% and 0.9% in 2018, respectively.



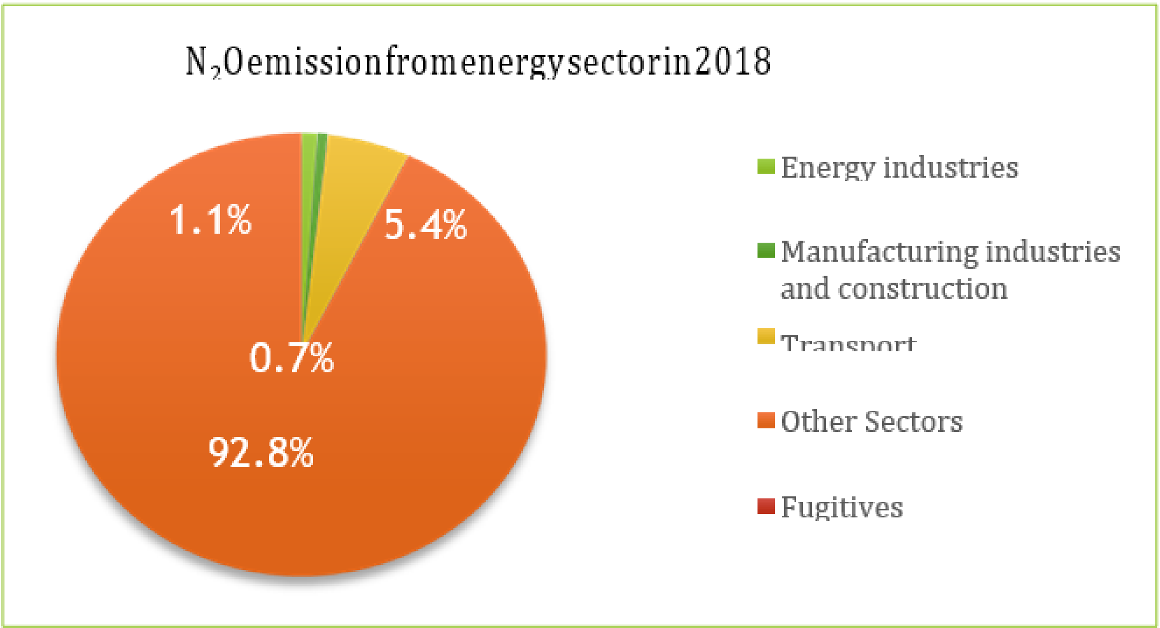


Figure 63 Comparison of N2O emissions of 2013 and 2018 for energy sector

The nitrous oxide emission in Ethiopia in the energy sector is dominated by other sectors (residential, commercial and institutional, and agriculture) (see 63). However, the share of nitrous oxide emission in Ethiopia reduced from 96.5% in 2013 to 92.8% in 2018.

2.14.15. Emission From Energy Sector by Sub-Sector

2.14.15.1. GHGs Emissions from Energy Industries

The Revised 1996 IPCC methodology stipulates that the national communications should include GHG emissions separated for each type of gas emissions and removals covering mainly the three main GHGs, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The bottom-up or sectorial approach was used to estimate Carbon dioxide (CO_2). The sectoral approach involves looking at the actual consumption of the energy industries (power generation or energy production. It identifies the specific sectoral consumers of fuel, including major emitters of energy-related GHGs, and thus provides a more detailed inventory of the CO_2 emissions from fuel combustion. The estimated CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users, which may not always be complete. This approach faces perennial problems of the incompleteness of data submitted by end-users due to recording errors and biases in addition to data collection challenges. Energy industry sector activities in Ethiopia are largely driven by the combustion of fossil fuels used in other industries for generating electricity. Emissions arise from these activities by combustion of diesel oil. Figure 64 show the GHGs emission from liquid fuels for the generation of electricity in energy industries from 1994 to 2018.

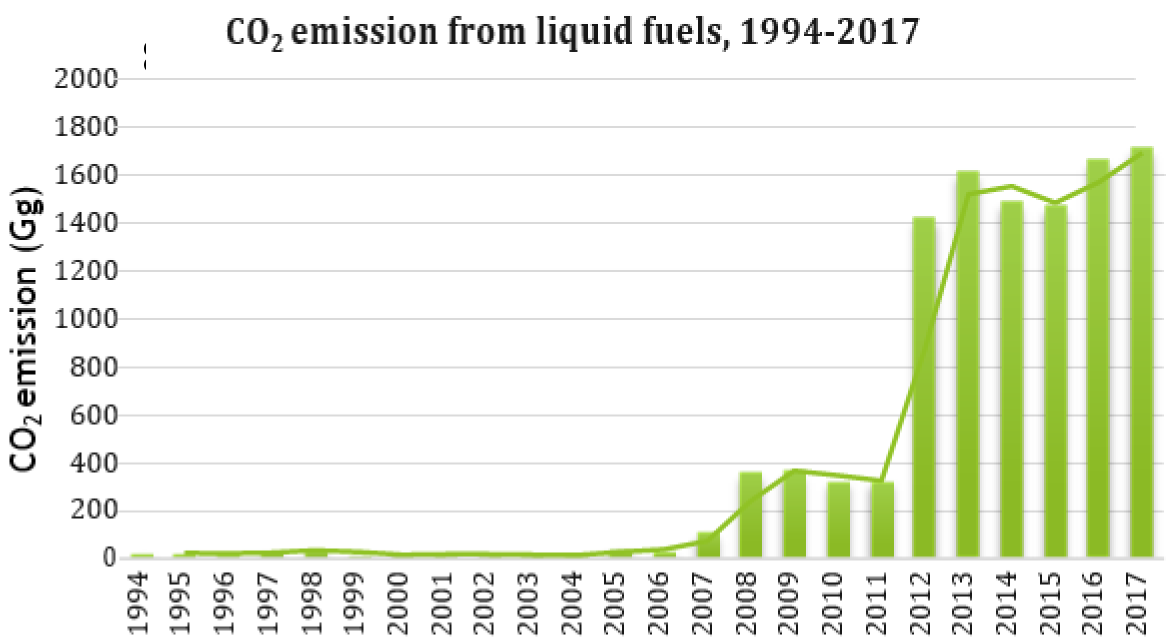


Figure 64 Emission of CO2 from liquid fuels in energy industries from 1994- 2018

Figure 64 shows the trend of CO_2 emission from energy industries while generating electricity from liquid fuels. The CO_2 emission dramatically increased from 114.3 Gg in 2007 to 1825.9 Gg in 2018, significantly increasing by 1497.5% due to the highest consumption of liquid fuels for electricity generation in the same inventory years. The highest level of CO_2 emissions (1825.9 Gg of CO_2) occurred in the year 2018 from energy industries only. Emissions have since been on a generally increasing trend. This trend is the result of building various industrial parks in Ethiopia (UN Industrials Development Organization, 2018). The other most important GHGs are methane (CH_4), and Nitrous Oxide (N_2O), and the annual variation of methane and nitrous oxide emissions from liquid fuels. The figure shows a rising trend in methane and Nitrous oxide gas emissions from liquid fuels. The peak years for emissions of CH_4 and NO_2 in the period under consideration were in the years 2007-2018. This was a result of an increase in the consumption of liquid fuels for electricity generation. It is also expected that as the country continues to grow in industries and more liquid fuels consumption, the trend line shows that methane and nitrous oxide emissions will continue to escalate.

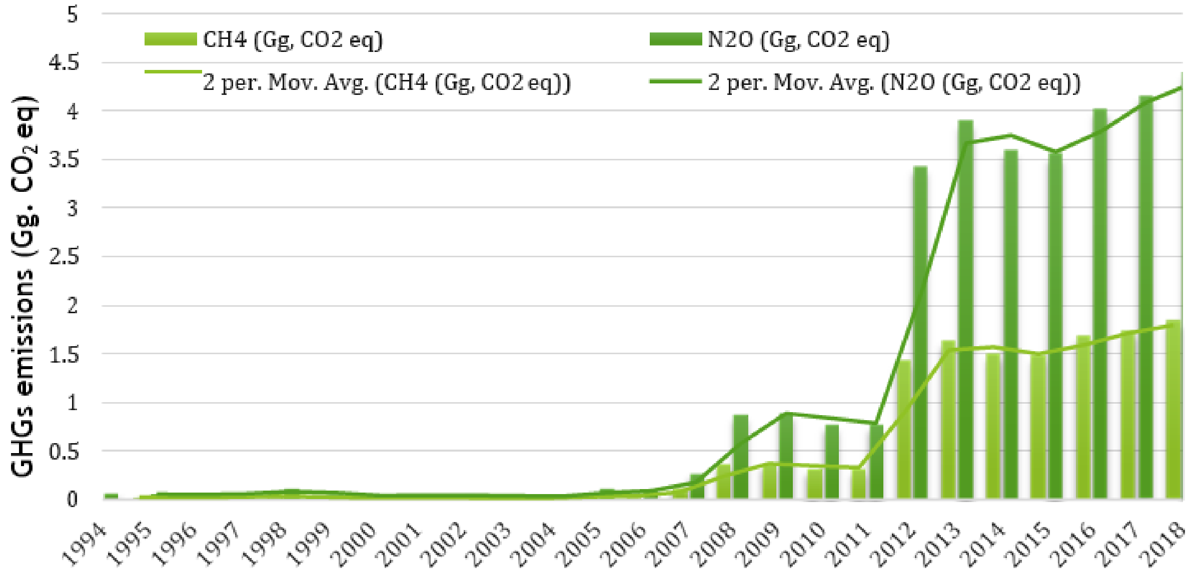


Figure 65 Total CH4 and N2O emissions (Gg, CO2 eq) from liquid fuels in energy industries from 1994-2018

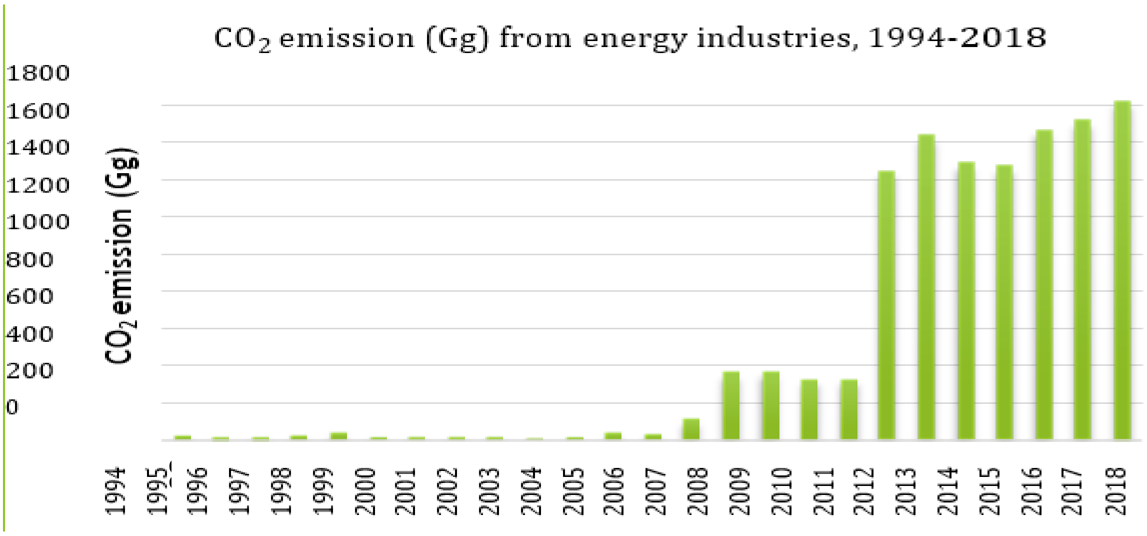


Figure 66presents the total aggregated emissions from the energy industries sector increased from 25.6386 Gg CO_2-eq in the year 1994 to 1825.9 Gg CO_2-eq in 2018. In this trend of CO_2 emission, liquid fuel combustion activities contributed 6433% and 7281% of total emissions of the energy sector compared to the total emissions from combustions of solid fuels in the year 2012 and 2013, respectively.

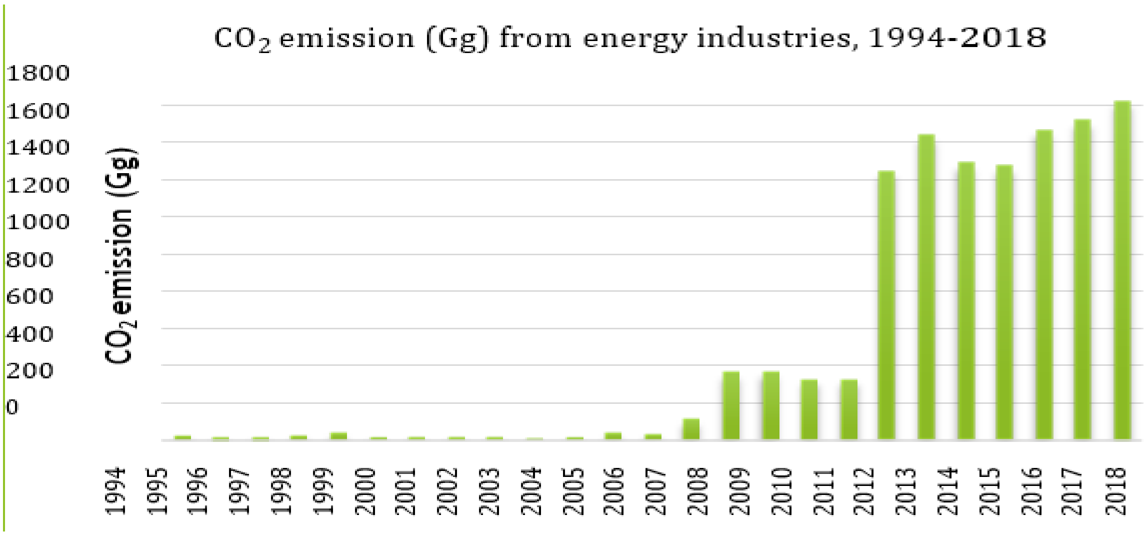


Figure 66 The total emission of CO2 from energy industries

While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately about 298 times more powerful than CO_2 at trapping heat in the atmosphere (IPCC, 2007).

Figure 67 shows the methane and nitrous oxide emissions, from 1994-2018 (Gg).

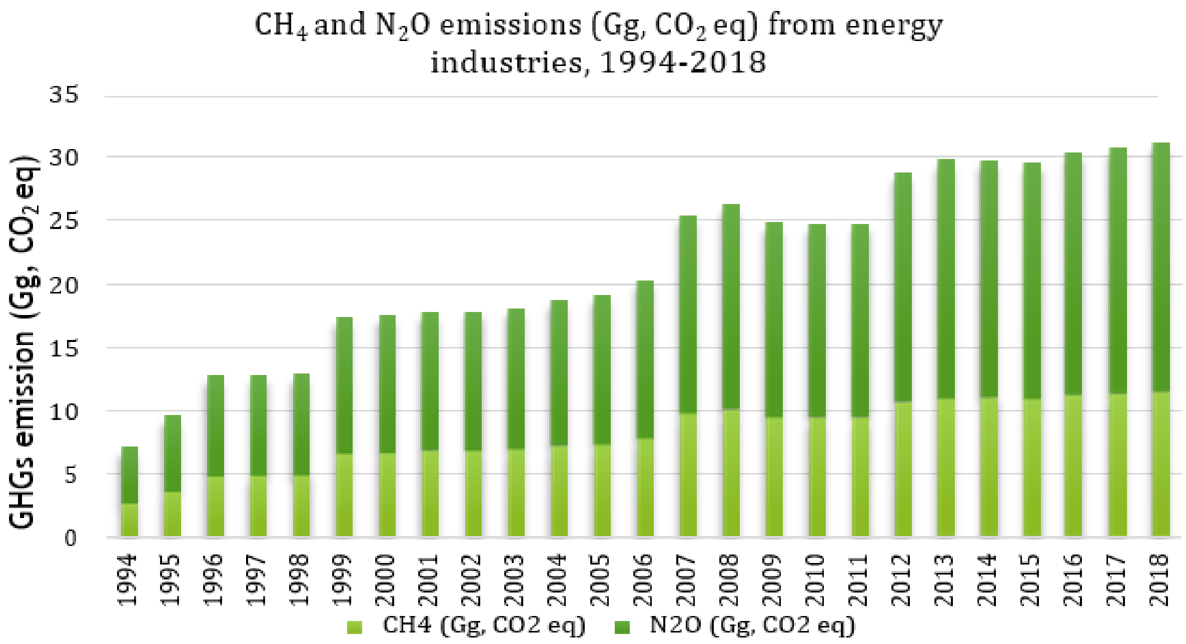


Figure 67 Total Emission of CH4 and N2O (Gg, CO2 eq) from energy industries

In 2018, within the energy industries sub-sector, biomass was the highest contributor with 83.9% of CH_4 and 77.6 % of N_2O from total emissions. During the period from 1994 to 2018, emissions increased by 76.2% of CH_4 and 77.9% of N_2O from Energy Industries as shown in Figure 67.

2.14.15.2. GHG Emissions from Transport Sub-sector

The general time trend for the emission of CO2 from the transport sub-sector is increasing significantly from 1994 to 2018. As it can be seen from the graph, the CO2 emission from the transport sector increased from 1014.5 Gg in 1994 to 6437 Gg CO2 in 2018, indicating that the CO2 emission is increased by 534% emission of CO2. The majority of CO2 emissions from the transportation sector are caused by road transportation, specifically by light and heavy-duty trucks, which produced 430 Gg of CO_2 in 1994 and 5890 Gg of CO_2 in 2018. However, there was only a 12% rise in CO_2 emissions from autos, increased from 441 Gg in 1994 to 495 Gg in 2018.

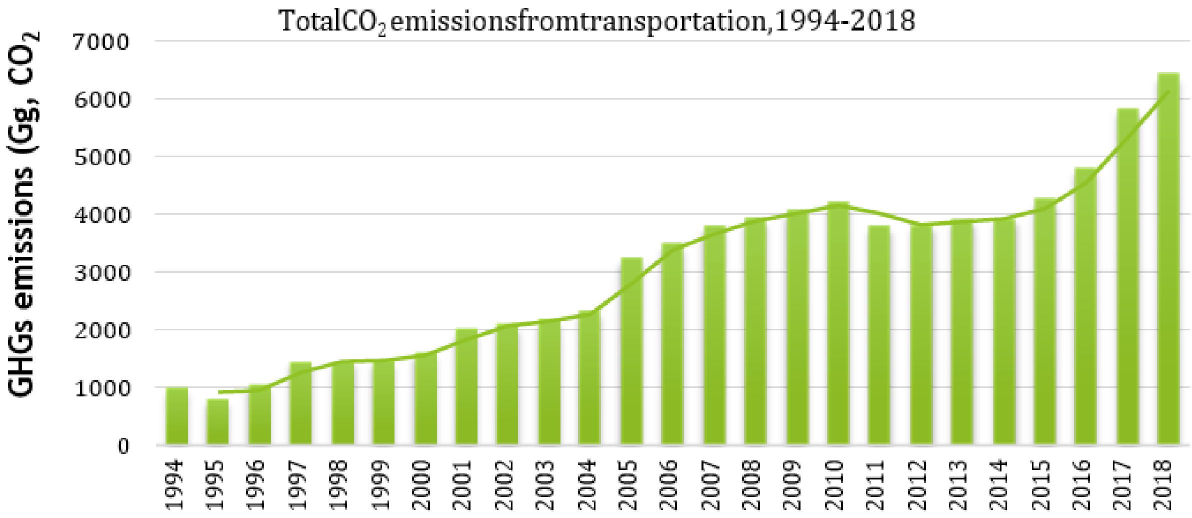


Figure 68 Total CO2 emissions from transportation of 1994 to 2018

The main reasons for the increase of CO_2 emission from road transportation is that the majority of cars in Ethiopia are old models, increasing traffic congestions, road side parking, poor integrations of different modes transport (Kassahun, 2018), all these different variables resulted in fuel consumptions by road transport and hence partly resulted in the increasing CO_2 emission from 1994 to 2018. The CO_2 emission from domestic aviation is the least contributor of CO_2 from the transport sub-sectors. It emitted only 80 Gg CO_2 in 1995 and increased by 68.75% (135 Gg CO_2) in 2018. The N_2O emission has increased from 14 Gg CO_2 eq in 1994 to 99 Gg CO_2 eq in 2018. The majority of emission of N_2O CO_2 eq is emitted from road transportation compared to the emission of civil aviation. Specifically, more than 85 of N_2O (12.8 Gg eq. CO_2) was emitted in 1994 and increased by 97.9% (97 Gg of N_2O CO_2 eq) in 2018, compared to the same years of inventory for domestic civil aviation. For the emission of CH_4, Figure 69 shows that CH_4 emission is slightly increased from 5.85 Gg eq. CO_2 in 1994 to 13.9 Gg CH_4 CO_2 eq in 2018. The majority of CH_4 emission is contributed from road transportation compared to that of domestic civil aviation. Specifically, road transportations emitted 8.5 Gg CH_4 eq CO_2 in 1994 and increased by 63.5% (13.9 Gg CH_4 eq. CO_2) in 2018. The domestic civil aviation contributed only 0.17% of CH_4 emission in 2018, showing the less emitter in the transportation sub-sectors.

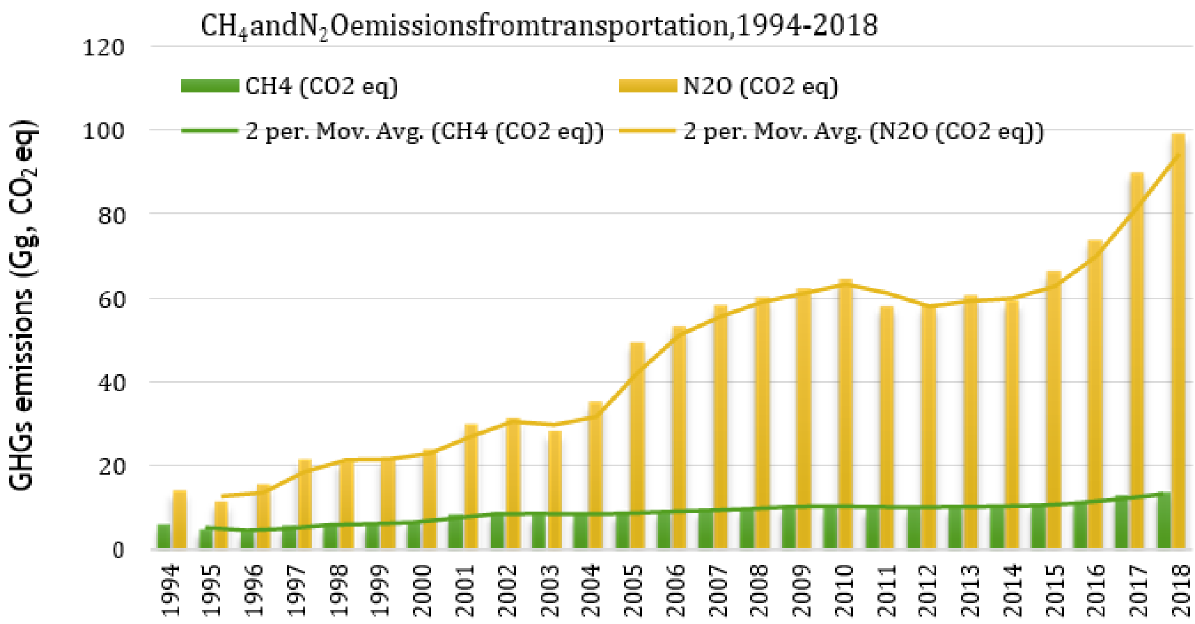


Figure 69 Total CH4 and N2O emissions from transportation sectors from 1994-2018:

2.14.15.3. Fugitive emissions from fuels

To develop the national inventory for the energy sector, specifically the fugitive sub- sector, the revised IPCC guideline was primarily used as the source for the methods and default values used. Additional methods or emission factors from the IPCC's good practice guidance and the 2019 refinement guidelines were also considered to improve the GHG estimates. Because primary energy sources are not explored and exploited in Ethiopia, only seismic, gravity, and magnetic studies are conducted, and potential emitted gasses (CO_2 and CH_4) are primarily the result of emissions from oil and natural gas transportation and distribution. Henceforth, the country relied entirely on petroleum product imports to meet rising national demand, particularly in the transportation sector. As a result, fugitive emissions reported from transportation and distribution of oil and natural gas become negligible compared to the other sub sectors listed in the energy sector. Moreover, for two consecutive years, 2012 and 2013, there was a high emission manifestation due to the underground and surface mining operation from the production of coal. Nonetheless, as can be seen from the tabulated data from 2014-2018 the emission contribution of the fugitive sector becomes null which will be attributed to the unfunctional companies working in coal production due to many potentially mentioned reasons.

For fugitive emissions, emission estimates were calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC Tier 1 Sectoral approaches were used as illustrated in the activity and source structure in the energy sector stated in Figure 1.1 of the guidelines (Vol 2 Energy, Chapter 1). The Sectoral Approach is a Bottom-Up method that estimates GHG emissions from fugitive processes in each source category. An increase in carbon dioxide emissions from 1999 to 2018 from fugitives in Ethiopia. presents methane emissions in fugitives in Ethiopia from 1994 to 2018. A significant amount of methane emissions was recorded in 2012 and 2013, with a value of nearly 14000 Gg CO_2-eq, and the reason for the sudden increase according to MoWE, was due to coal production (mining and post-mining) in 2012 and 2013.

Fugitive emissions from underground mining arise from both ventilation and degasification systems. These emissions are normally emitted at a small number of centralized locations and can be considered as point sources. They are amenable to standard measurement methods. On the other hand, for surface mining the emissions of greenhouse gases are generally dispersed over sections of the mine and are best considered area sources. These emissions may be the result of seam gases emitted through the processes of breakage of the coal and overburden, low temperature oxidation of waste coal or low-quality coal in dumps, and uncontrolled combustion. Measurement methods for low temperature oxidation and uncontrolled combustion are still being developed and therefore estimation methods are not included in this chapter. The predominance of solid fuels is directly proportional to fugitive emissions of CH_4 from fuels. This is evident that the exploration and mining of solid fuels, particularly coal production prevails. It is clear that the activity data and emission factors already include all the methane likely to be released from mining activities. When we look into the fugitive emissions from fuels, the solid fuels are predominantly taking the lion share among other fuel types in the overall year from the 1994 up to 2018 activities.

Table 37 **Error! Reference source not found.** reproduces the recalculated emissions for the base year 1994, 2000 and end year of the previous report 2013 in sub-sectoral presentations.

Moreover, Table 37 presents the overall recalculated emissions on year bases in the specified time series, 1994-2013.

In the previous report, estimations for 1994 and 2013 were made in accordance with IPCC 1996 Revised and 2006 Guideline. Though Tier 1 was employed in both reports to estimate the total emissions, the previous report differs from the current inventory in that it covers fewer activity data.

2.14.16. Comparison of the reference approach and the Sectoral approach results

Estimation of the national GHGs inventory using reference approach involved a straightforward calculation of the country's annual GHG emissions based on the apparent consumption of fuels, which is defined as the difference between fuel production and imports and the sum of exports, global consumption, and variations in fuel stocks, on the one hand.

The average percentage difference between reference and sectoral approaches over the previous six years (2013–2018) for the estimation of imported liquid and solid fuels was determined to be eight percent. The difference between the two approaches for apparent liquid and solid fuels consumption in the previous two years, 2017 and 2018, were found to be 0.97 and 6.29%, respectively.

Table 37 : Apparent liquid and solid fuel consumption from reference approach (TJ), 2013-2018

Year	Reference	Sectoral	% Change
2013	140821.6	115401.2	22.03
2014	126136.4	122490.7	2.98
2015	134325.0	147547.3	-8.96
2016	156973.0	146353.8	7.26
2017	165861.0	167484.8	-0.97
2018	171534.0	183042.6	-6.29

These figures are based on the nation's overall energy balance. The sectoral approach used to determine the emissions of imported liquid and solid fuels in 2018, which came to 14392.1256 Gg of CO_2, whereas the reference method estimates 11025.0077 Gg of CO_2 emission. In general, the average percentage difference between reference and sectoral approaches over the previous six years (2013–2018) for the estimation of CO_2 from imported liquid and solid fuels was determined to be 10.38%.

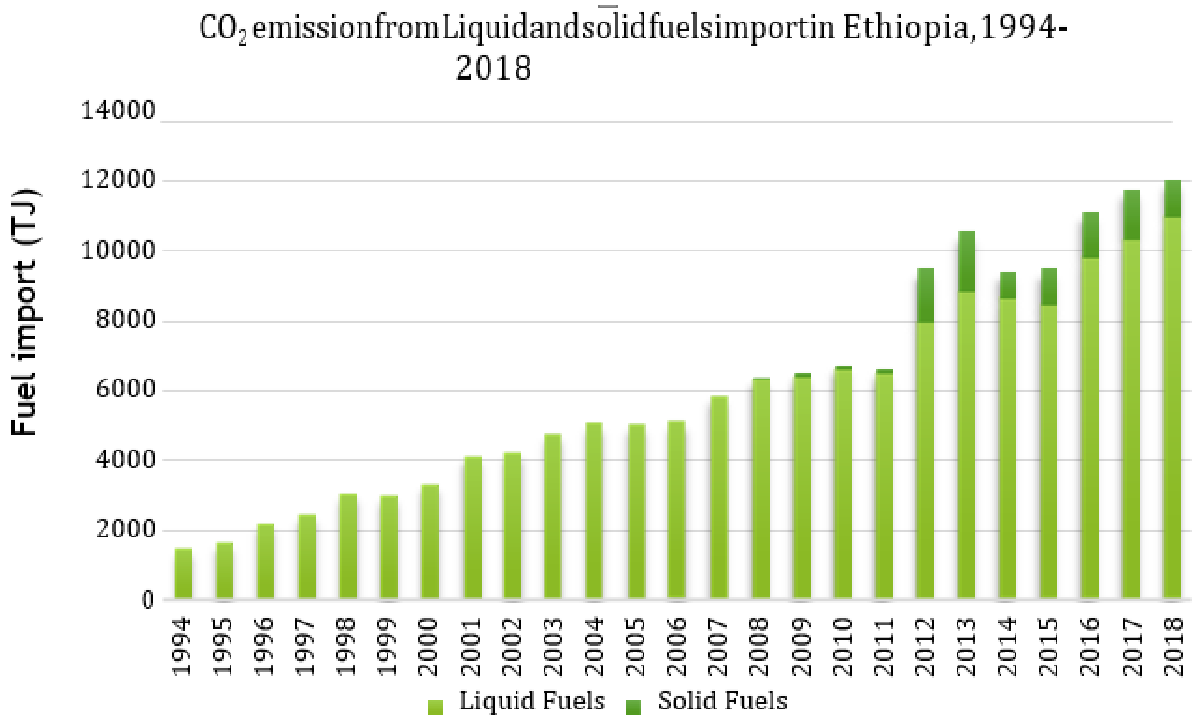


Figure 70 CO2 emission estimation from energy sector using reference approach for imported liquid and solid fuels, 1994-2018

The results obtained employing the reference approach were usually higher than those obtained using the sectoral approach. This is because the national energy balance lacks sufficient levels of disaggregation, making it difficult to distinguish between domestic and international consumption, as well as the accompanying emissions from air transport. Hence, there's a chance that the calculation done using the reference approach may overestimate consumption and as a result greenhouse gas emission (Table 40)

Table 38 Comparison of reference and sectoral approaches for CO2 emissions estimation from liquid and solid fuels (Gg), 2013-2018

Year	Sectoral	Reference	% Change
2013	8262.858	10559.28	27.79
2014	8867.56	9404.0987	6.05
2015	10629.28	9471.2	-10.90
2016	10632.28	11096.52	4.37
2017	12242.33	11741.126	-4.09
2018	13387.54	12029.59	-10.14

2.15. Industrial processes and product use (IPPU) sector

Greenhouse gas emissions from the IPPU sector are produced from a wide variety of industrial processes for the manufacture of new products and from the use of greenhouse gasses in products. During these processes, many different greenhouse gasses, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), can be produced. In this chapter, estimates of GHG emissions from five main categories: 2.A- Mineral Industry Category (Cement, Lime, Glass and Ceramic Production), 2.B- Chemical Industry Category (Soda Ash Production), 2.C - Metal Industry (Iron and Steel Production), 2.D - Non-Energy Products from Fuels and Solvent Use (Lubricant, Paraffin Wax Use, Asphalt and Bitumen), and 2.F - Product Uses as Substitutes for Ozone Depleting Substances (Refrigeration and Air Conditioning and Foam Blowing Agent) are provided.

The GHG inventory addresses direct GHG emissions of carbon dioxide (CO_2) and HFCs from the IPPU sector. Estimates for the years 2014-2018 have been made. Estimates for the years 1994 to 2013 have been recalculated whenever necessary to reflect improved activity data or emission factors as appropriate, for the sake of consistency in reporting.

2.15.1. Methodological Framework

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3 was used for estimating emissions in combination with the IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The decision tree in each source category was applied to determine which tier level was adopted for computing the GHG emissions. Hence, Tier 1 level was used because of scarcity of disaggregated information on the technologies used in the production processes and unavailability of national specific emission factors. Thus, IPCC default emission factors were adopted. In addition, for emission estimation from asphalt and bitumen use category, EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2019) was used, as recommended by IPCCguideline.

The GHG inventory for the IPPU covers the period 1994-2018. Since the submission of the second national communication (SNC), the Ethiopian National GHG Inventory has been updated as follows:

The IPPU sector GHG inventories reported in the SNC covered the period 1994- 2013. These are now recalculated due to the availability of improved activity data. Accordingly, the recalculations have produced differences from the IPPU sector GHG inventory values for the period 1994 – 2013 reported in the SNC. The annual GHG inventories for the period 2014 to 2018 are calculated and added to the time-series.

The estimation of the emissions was computed using the IPCC 2006 guideline methodologies where generally the activity data were multiplied by the respective emissions/removal factors.

2.15.2. Data Sources

Activity data for the IPPU categories covered in the inventory were mainly obtained from the Ethiopian Statistical Services (ESS), Ministry of Industry (MOI), Environment Protection

Authority (EPA), Chemical & Construction Inputs Industry Development Institute (CCIIDI) and Manufacturing Technology & Engineering Industry - Research & Development Center (MTEIRDC). Table 41**Error! Reference source not found.** provides an overview of data sources and data type used in the GHGestimation

Table 39 Summary of Activity Data Type and Sources

IPCC category/sub category	Data Type	Data Source
2 - Industrial Processes and Product Use		
2.A - Mineral Industry		
2.A.1-Cement production	Annual production ofclinker	MOI/ESS
2.A.2 - Lime production	Annual production of lime (High calcium lime & Hydraulic lime)	MOI, CCIIDI, ESS
2.A.3 - Glass Production	Annual production of Glass	MOI
2.A.4 - Other Process Uses of Carbonates		
2.A.4.a -Ceramics	Annual production of Clay bricks, Sanitary and tile ceramics	MOI, CCIIDI, ESS
2.B - Chemical Industry		
2.B.7 - Soda Ash Production	Annual production of Soda Ash	MOI/EPA
2.C - Metal Industry		
2.C.1-Iron and Steel Production	Annual production of Steel, Technology Type	MOI, MTEIRDC, ESS
2.D - Non-Energy Products from Fuels and Solvent Use		
2.D.1-Lubricant Uses	Lubricant use data	MOI
2.D.2-Paraffin Uses	Paraffin Wax use data	MOI
2.D.3.b- Road paving with asphalt	Asphalt production and use	MOI
2.F - Product Uses as Substitutes for Ozone Depleting Substances		
2.F.1 - Refrigeration and Air Conditioning		
2.F.1.a - Refrigeration and Stationary Air Conditioning	Yearly Refrigerant consumption	EPA/MOI
2.F.2 - Foam Blowing Agents	Yearly Blowing Agent consumption	EPA/MOI

2.15.3. Constraints and data gaps

Several constraints and gaps were encountered during the inventory preparation particularly during data collection and GHG estimation for the IPPU sectors. These gaps and constraints are as follows:

- Lack of country specific emission factor for key category of the sector
- National average annual cullet ratio (fraction) for estimation of GHG from glass production was notavailable.
- Growth rate in new equipment sales for estimating HFCs from refrigeration and air conditioning was notavailable.

2.15.4. Planned Improvements

Positive areas are identified for future improvements during the inventory to enhance the quality of the report.

1. Identify, track, and monitor any new potential source of emissions for inclusion in inventories in accordance with IPCC guidelines.
2. Identify additional data collection sources for cement and lime production. Particular attention should be given to collecting accurate process-based data for lime and cement production from each industry.
3. Develop country specific emission factor of the key category in the sector

2.15.5. Quality Control and Quality Assurance (QA/QC)

Appropriate QA/QC system has been developed and implemented in line with the 2006 IPCC Guidelines for National GHG inventories. Quality controls applied for determining the National GHG Inventory from the IPPU sector include generic quality checks of the calculations, data processing, completeness, and applicable documents.

A national system for quality control (QC) of data being gathered within the various institutions is presumed to exist in Ethiopia. It is assumed that all data are quality controlled at different stages of the process until the final quality assurance (QA) is made by the institutions. Thus, the initial phases of the control system on archiving databases remained beyond the IPPU GHG inventory team. Therefore, the QA/QC process started from the time the AD was received from the different data sources.

The main QC activities of IPPU GHG emission estimation team include, checking the integrity of the activity data sources, cross checking data consistency with other sources, checking the correctness in parameters, units of activity data and conversion factors, and checking those assumptions and criteria for activity data (AD) and emission factors (EF) selection are documented. The team also determined that the results of the annual inventories, emission factors and assumptions applied as well as the methodologies used were reasonable.

2.15.6. Uncertainty Assessment

The process for estimating GHG emissions has inherent uncertainties. It is an important component of a GHG inventory. Estimating uncertainties attached to emissions provides crucial information on the categories to be prioritized for maximizing resource allocation to improve the quality of the inventory. Most of the time, use of expert judgment to inform or interpolate and extrapolate in filling of time series data gaps for AD and default emission factors are possible sources of uncertainties in the inventory. For this Inventory, a Tier

1 uncertainty analysis of the aggregated figures as required by the 2006 IPCC Guidelines, Vol. 1 (IPCC, 2006) was performed. Since default EFs have been used in the compilation of the inventory, the mid value recommended in the IPCC Guidelines were adopted for calculating uncertainties. In cases where IPCC recommended a particular methodology, the uncertainty level was derived according to the proposed procedure and used in the uncertainty analysis.

The uncertainty analysis has been performed using the tool available within the IPCC 2006 Software. In most cases, the uncertainty values allocated to AD and EFs from within the range recommended by the IPCC Guidelines were applied.

Uncertainty estimates for cement production are primarily caused by uncertainties associated with activity data, and to a lesser extent by uncertainty associated with the clinker emission factor. For Tier 1, the major uncertainty component is the clinker fraction of the cement (s) produced. The uncertainty in data on clinker production tonnes, when available, is about 1-2%. Most CO_2 emissions calculations related to lime production were based on hydraulic lime production and the uncertainty value for estimation of CO_2 emissions from lime production is ±15%. The uncertainty for glass production was also calculated about 16.5%. This is due to the activity data converted to mass from the yearly volume of glass produced in the country. Uncertainty associated with use of the Tier 1 emission factor and cullet ratio is significantly higher, and it was assumed the IPCC default value which is value of ±60%. The combined uncertainty also found 62.277% for glass production. Expert judgment is that uncertainty in ceramic production data is ±10%, as reported clay bricks production which was assumed most to account for carbonaceous clay. As regards soda ash production, the uncertainty is mainly due to soda ash production data and it is ±5%. The uncertainty for Iron and Steel Production, lubricant and paraffin use activity data also assumed to be 50%. Finally, the uncertainties for refrigeration and stationary air conditioning and foam blowing agent activity data were set to be ±60 and ±50%, respectively

2.15.7. Emission Factors

Default emission factors were drawn from the sections of the Reference Manual (Volume 3) of the 2006 IPCC Guidelines that cover industrial processes and product uses (IPPU). The EFs used for the different source categories are listed in **Error! Reference source not found.**.

Table 40 Emission Factors of the IPPU sector

IPPU Category	Production Process	IPCC 2006 Guideline	Table and page No.
2.A. Mineral Industry	Cement	V3_2_Ch2 Mineral Industry	Chapter 2.2.1.2 Page 2.11
	Lime	V3_2_Ch2 Mineral Industry	Table 2.4 Page 2.22
	Glass	V3_2_Ch2 Mineral Industry	Chapter 2.4.1.2 Page 2.29

	Ceramics[a]	V3_2_Ch2 Mineral Industry	Table 2.1 Page 2.7
2.B. Chemical Industry	Soda Ash	V3_3_Ch3 Chemical Industry	Chapter 3.8.2.1 Page 3.54
2.C - Metal Industry	Iron and Steel	V3_4_CH4 Metal Industry	Table 4.1 Page 4.25
2.D - Non-Energy Products from Fuels and Solvent Use	Lubricant Uses	V3_5_Ch5 Non-Energy Products	Table 5.2 Page 5.9
	Paraffin Uses		Chapter 5.3.2.2 Page 5.12
	Asphalt and bitumen [d]	EMEP CORINAIR - SNAP 040611	Table 3.1 Page8
2.F - Product Uses as Substitutes for Ozone Depleting Substances	Refrigeration and Air Conditioning [b]	V3_7_Ch7 ODS Substitutes	Chapter 7.1.2.3 Page 7.18
	Foam Blowing agent [c]		

2.15.8. Emission factors for refrigeration and air conditioning

The different gasses used as ODS substitutes have different GWP. EFs and details on the gasses are given in T. However, due to lack of country specific data, for some parameters the IPCC software default values for emission estimation were used.

T

	2.F.1.a - Refrigeration and Stationary Air Conditioning	**2.F.2 - Foam Blowing Agents**
	HFC-134a	HFC-243fa
Year of introduction	1995	1995
Growth Rate in New equipment sales	1%	NA
Assumed Equipment Lifetime (years)	15	NA
Emission Factor for installed base	15%	15%
Emission Factor for subsequent years	NA	1.5%
% of Gas destroyed at End of Life	0.00	NA

NA: Not applicable

2.15.9. Industrial Activity Data by Category

The activity data in terms of country production for each selected industrial category are presented below Table 43

Table 41 Production capacity by category

Year	IPCC category code											
	2.A - Mineral Industry					2.B - Chemical Industry	2.C - Metal Industry	2.D - Non-Energy Products from Fuels and Solvent Use			2.F - Product Uses as Substitutes for Ozone Depleting Substances	
	2.A.1- Cement production (Clinker) (tones)	2.A.2-Lime production (tones)	2.A.3-Glass production (tones)	2.A.4 - Other Process Uses of Carbonates 2.A.4.a-Ceramics		2.B.7-Soda Ash Production (tones)	2.C.1- Iron and Steel Production (tones)	2.D.1- Lubricant Uses (TJ)	2.D.2- Paraffin Uses (TJ)	2.D.3.b- Asphalt and bitumen (tones)	2.F.1 - Refrigeration and Air Conditioning 2.F.1.a- Refrigeration and Air Conditioning HFC-134a (tones)	2.F.2- Foam Blowing Agent HFC-243fa (tones)
				Clay Bricks (tones)	Sanitary and tile ceramics (tones)							
1994	375857.1	2722	5151.38	40392.17	---	17505	99.12	---	---	---	---	---
1995	493102.2	4935	8305.52	39895.86	---	15006	86.76	---	---	---	---	---
1996	544271.5	7207	13344.88	32393.14	---	20000	67.97	---	---	---	---	---
1997	626975.4	7332	12989.4	41103.56	---	11028	109.63	---	---	---	---	---
1998	633463.9	6619	6569.31	40,923.65	---	9454	95.33	---	---	---	---	---
1999	620707.8	6913	12148.32	40,139.88	---	8105	79.04	---	---	---	---	---
2000	489611.2	9273	3697.94	41,674.34	---	3805	94.72	---	---	---	---	---
2001	1197600	11350	3731.29	43,699.94	---	7543	131.43	---	---	---	---	---
2002	2.2E+08	7805.01	3215.76	45,725.55	---	3843	136.21	---	---	---	---	---
2003	1141200	10532	608.81	43,347.35	---	4377	137.06	---	---	---	---	---
2004	1032000	15679	3831.34	29,642.71	---	6444	274.67	---	---	---	---	---

2005	2213400	11850	3418.03	51,255.38	---	8207	218.89	---	---	---	---	---
2006	1377600	8141	7851.05	28,730.72	---	4099	471.02	---	---	---	0.01	---
2007	1328400	4461	8586.59	92,971.08	---	1000	1981.44	10.87	275.86	2393.97	0.01	---
2008	1357800	4068	4784.23	28,763.81	---	1597	2015.24	6.74	224.68	4609.49	0.02	---
2009	1302000	3829	4694.3	27,063.92	---	16000	2409.55	20.7	227.69	4428.07	0.01	---
2010	2186400	3254	3814.32	36,489.86	---	529	1537.52	22.65	206.8	5892.93	0.0007	---
2011	3021000	2481	6065.47	38,067.74	---	948	590.15	7.96	297.20	3831.71	0.20	---
2012	5372400	5621	8645.51	28,902.37	---	1395	449.68	11.76	282.99	2853.00	0.02	3.32
2013	5856000	127930	4320.55	2,979.99	---	1877	961.61	9.54	351.41	4831.64	0.20	6.65

2.15.10. Cement production

The activity data represents the total clinker use for the production of both Portland Pozzolana Cement (PPC) and Ordinary Portland Cement (OPC) domestically. The information covers all Ethiopian cement industry from 1994 to 2018.

Lime production

The national yearly production of lime from 1994 to 2018 was included. Due to lack of information regarding the type of lime, the emission estimation was made by assuming that High Calcium Lime would account for 40% of annual production and Hydraulic Lime for 60%.

Ceramics

Based only on data for the years 2014 to 2018, the national production of Ceramics Tiles and Sanitary ware was used to calculate GHG emissions from other processes uses of carbonates within the mineral industry category. Additionally, the national annual production of clay bricks was considered in this subcategory using the default carbonate content for clay goods, which was set at 10% in accordance with IPCC guidelines. The activity data given in table 2 shows 10% of the actual annual production of clay bricks. Due to incomplete data, interpolation was used to estimate clay brick production for the years 2014 and 2018.

Soda Ash Production

In addition to being used as a raw material in the production of glass, soap and detergents, pulp and paper, and water treatment, soda ash is also utilized in many other industries. For the purpose of estimating emissions from this category, the amount of trona used or soda ash produced (in tonnes of trona utilized or tonnes of natural soda ash for the years 1994 to 2018) .

Iron and Steel Production

The information in Table 2 only pertains to the Ethiopian Iron and Steel Factory-ROSE. This factory is the only single factory which uses the electric arc furnace (EAC) melting technology for its production. Furthermore, the factory uses this technology for 30% of its production. Steel production in Ethiopia occurs mostly at secondary facilities, which produce steel mainly from recycled steel scrap. Steel industries in Ethiopia produce steel castings by melting scrap, alloying, molding, and finishing. Electric induction furnaces are used almost exclusively in the steel industries in Ethiopia for melting and formulating steel. According to IPCC guidelines, there are no appreciable CO_2 or CH_4 emissions from steelmaking processes using electric induction furnaces. Therefore, we only included an estimate of the emissions from the Ethiopian Iron and Steel Factory-ROSE factory in the current report. The estimated activity data were based on the total output contribution to the nation. From the available data in the period 2014 to 2020, the factory contribution was calculated from its iron bar production capacity and was estimated at around 1%. As a result, after determining the nation's annual output of iron and steel from ESS, the factory's total annual production was estimated by assuming a 1% share, which is similar to the share of iron bar production.

2.15.11. GHG Emissions from IPPU Sector

Figure 74 demonstrates the National CO_2 emission Inventory time series from IPPU sector

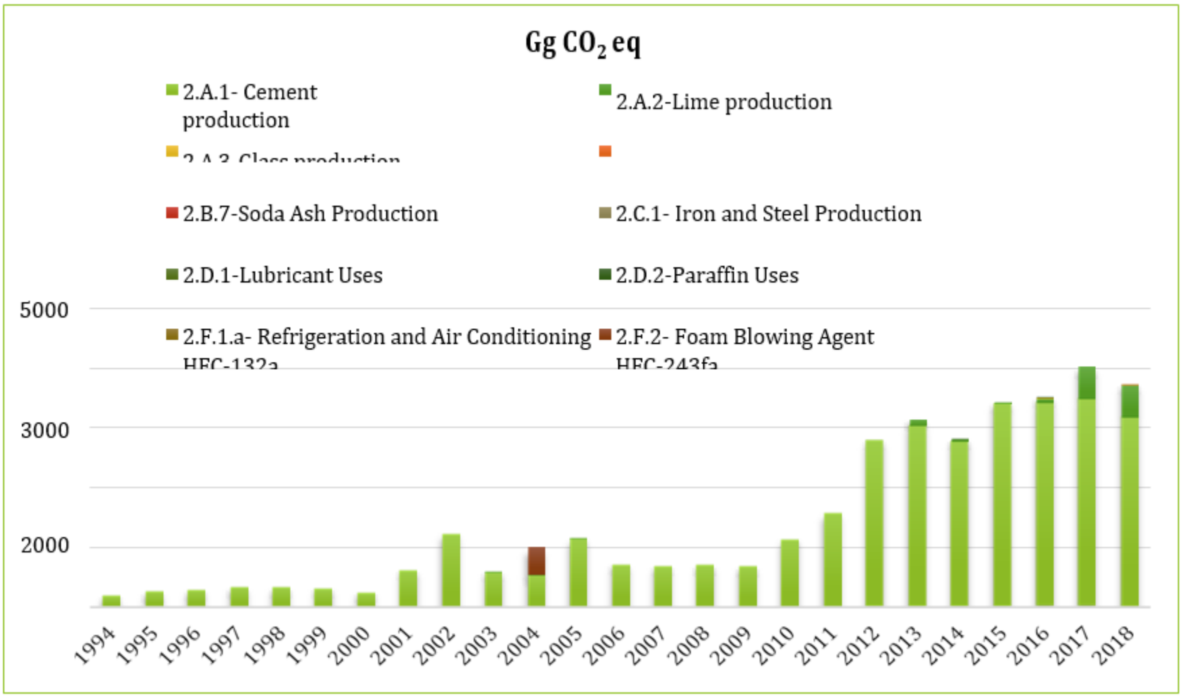


Figure 71 National GHG Inventory time series from IPPU categories

Total emission time series for the IPPU sector, ranged between 201.311 Gg CO_2- eq and 3747.85 Gg CO_2-eq during the period 1994 to 2018 with an annual average of 1427.84 Gg CO_2-eq. Also, as presented in Figure 2.39(above), Ethiopia's National GHG Inventory time series in terms of IPPU sector shows a steady increase in trend, with significant increments starting from 2012 CO_2 emissions increased by about 43% from 1570.92 Gg in the year 2011 to 2793.65 Gg in 2012. This is because the industrial investment in the country like cement plants (Habesha and Dangote cement having annual production capacities of 1.4 and million tonnes per annum, respectively and others.) are increased. Based on the recalculated value, in 2013 the cement industry is responsible for 97 % of the aggregated emissions followed by the lime production with 3 % Figure 74. The contribution of the rest of the industrial processes and product uses was almost 0 %. Similarly, in 2018, the cement and lime production contributed the highest share of CO_2 emission, which were 85% and 15%,

Respectively. Iron and steel production and Cement production, were indicated in the SNC with 48% and 51% contribution, respectively. However, from recalculation in the period of 1994 to 1993, and emission estimation in the period of 2014 to 2018, cement has the lion share in the national GHG emission from IPPU sector.

2.16. Agriculture, forestry, and other land use (AFOLU) sector

Agriculture, forestry, and other land use (AFOLU) sectors is a vital sector in the GHG emission and removal in Ethiopia. This sector is unique in that it plays a linchpin role both on the emission and removal sides. It emits CO_2 and non-CO_2 gasses such as methane (CH_4) and nitrous oxide (N_2O). Over the last two decades, the country has experienced rapid land-use change which was responsible for the CO_2 emission. The land-use change has put enormous pressure on Ethiopia's forests. Moreover, due to its location in the tropics forest fires are more frequent and widespread in the country. Burnt biomass emits many gaseous substances such as CO_2, CO, and NVOM. The crop production subcategory is also the source of direct and indirect N_2O emissions. Crop production and livestock are the biggest emitters of all the economic sectors. Liming, Urea application, Direct N_2O emissions from managed soils, Indirect N_2O emissions from managed soils, enteric fermentation from ruminant and non-ruminant cattle, and manure management are responsible for the emission of GHG with high global warming potential such as CH_4 and N_2O.

2.16.1. Methodological Framework

Data collection was done between October 2021 and June 2022. The main institutions and ministries contacted for the activity data collection were:

- Central Statistical Service(CSS)
- Ethiopian Geo-Spatial InformationAgency
- Ministry of Agriculture(MoA)
- Agricultural ResearchCenter
- Ethiopian Environmental Protection Authority (EPA)
- Ethiopian Environment and Forest Research Institute
- Ethiopian forest development

The following section presents detail of the activity data acquisition method by subcategories.

2.16.2. Activity Data for The Livestock Subcategory

The Intergovernmental Panel on Climate Change (IPCC) recommends using a more advanced (Tier 2) method to quantify livestock GHG emissions in national GHG inventories. To this end, the Ministry of Agriculture (MoA) developed IPCC, tier 2 (IPCC, 2006) emission estimation approach to estimate the GHG emission from the cattle which better reflects the management practices, diets and animal productivity in different production systems (MoA, 2015). The Tier 2 approaches require more detailed information on different types of livestock in a country, livestock production systems, data on livestock weight, weight gain, feed digestibility, milk yield and other factors reflecting management practices and animal performance. The livestock population category and subcategories were defined to create relatively homogenous sub-groupings of animals based on difference in production systems, breed, age, sex, production objective(dairy, meat, multipurpose). Based on IPCC classification for cattle the relevant categories in Ethiopia are: high producing dairy cows (pure exotic), low producing (crossbreed), othercattle(indigenousmultipurposecattle),whileotherlivestockspecies are: sheep, goats, camels, horses, mules/ asses, and poultry. The majority of cattle populations in Ethiopia are indigenous types but a small number of exotic dairy cattle breeds and crossbreeds are found in urban and suburban areas. Dairy cows in the Ethiopian context are defined here as mature cows (pure exotic and crossbreed) that are producing milk in commercial quantities for human consumption (IPCC, 2006). In Ethiopia the dairy cow population is comprised of two well-defined segments: (i) high- producing exotic dairy cow population found in urban and peri-urban commercial operations (commercial intensive); and (ii) low producing dairy cow population managed under medium input production system (smallholder intensive) (MoA, 2015). The dairy cow category does not include indigenous cows kept for multipurpose production (meat, milk and draft power) and cattle managed under pastoral production system. Ethiopia is a country with distinct production system differences with four major production systems i.e., the highland mixed crop livestock production system, the pastoral and agro-pastoral production system, commercial intensive system and smallholder intensive system Table 47

Table 42 Classification of the cattle categories into subcategories and division

Livestock species category	Livestock species sub category	Production system		Livestock division
Cattle	Dairy cow	Commercial system	intensive	Adultpureexoticdairycows(3-10 years)
		Commercial system	intensive	Adultpureexoticmales3-10years
		Commercial system	intensive	Pure exotic calves (<6 months) male & female
		Commercial system	intensive	Pure exotic calves (6 m - < 1 yr.) male & female
		Commercial system	intensive	Pureexoticgrowingmales(1-<3 years)
		Commercial system	intensive	Pure exotic growing females (1-< 3 years)
		Smallholder system	intensive	Adultpureexoticdairycows(3-10 years)
		Smallholder system	intensive	Adultpureexoticmales3-10years
		Smallholder system	intensive	category not used
		Smallholder system	intensive	Pure exotic calves (<6 months) male & female

	Smallholder intensive system	Pure exotic calves (6 m - < 1 yr.) male & female
	Smallholder intensive system	Pure exotic growing males (1-<3 years)
	Smallholder intensive system	Pure exotic growing females (1-< 3 years)
Other cattle	Pastoral & agro pastoral system	Adult multipurpose cows>3years
	Pastoral & agro pastoral system	Adult males used for draught (3-10 years)
	Pastoral & agro pastoral system	Adult males used for breeding & other purpose (>3-10 years)
	Pastoral & agro pastoral system	Pre-weaning calves < 6 months (male & female)
	Pastoral & agro pastoral system	Post-weaning calves (6 m-1 yr.) male & female
	Pastoral & agro pastoral system	Growing males 1-3 years
	Pastoral & agro pastoral system	Growing females 1-3 years
	Mixed crop livestock system	Adult multipurpose cows>3years
	Mixed crop livestock system	Adult males used for draught (3-10 years)
	Mixed crop livestock system	Adult males used for breeding & other purpose (>3-10 years)
	Mixed crop livestock system	Pre-weaning calves < 6 months (male & female)
	Mixed crop livestock system	Post-weaning calves (6 m-1 yr.) male & female
	Mixed crop livestock system	Growing males 1-3 years
	Mixed crop livestock system	Growing females 1-3 years
	Mixed crop livestock system	Adult males (>3 years) smallholder feedlot
	Mixed crop livestock system	Adult males (>3 years) commercial feedlot

The estimated cattle populations were obtained from the MoA for the 1994-2018 periods. Seasonal births or slaughters may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted to the original form of the population data as it was received from farmers, Central Statistical Service or from other sources but the adjustment was made by the MoA. The population data for other livestock categories (sheep, goats, camels, houses and mule/asses) was obtained from the Central Statistical Service.

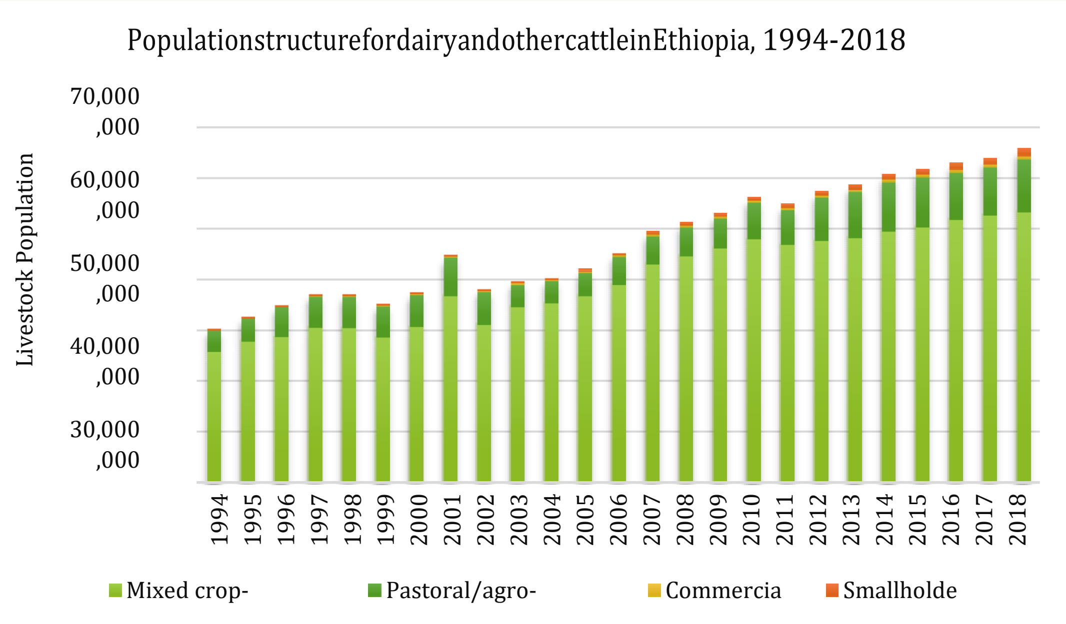


Figure 72 Livestock population in sub category and production system

The commercial intensive production system is based on the use of pure exotic breed and crossbred dairy cows for commercial purpose, manures are managed in liquid based-system or pit form, feed and feeding system is based on concentrate supplementation. The mixed crop-livestock production system is part of the subsistence farming system found in mixed highland areas. Feed resources are mainly natural grazing, crop residues and a small number of cultivated forages. In this system most livestock manure is left on pasture/grazing land, used as fuel for energy sources or construction purposes. The pastoral and agro-pastoral production system is found in an extensive rangeland area of the lowland part of the country. The major feed resources are grass, shrubs, and browse from rangeland. Livestock manure is managed as a solid left on range land/pasture.

2.16.3. Activity Data for The Crop Production Subcategory

From the crop production subcategory, specific N sources considered for estimating N_2O emission from managed soils are inorganic N fertilizer, organic N fertilizer, urine and dung deposited by grazing animals, and N from crop residues. Nationally published data from CSA on synthetic fertilizer application (annual consumption of synthetic fertilizers, which includes UREA, DAP, and NPS (Nitrogen, phosphorus, and Sulfur)), area of crop cultivation, and crop production for the year 1994-2018 was collected. The amount of solid manure/slurry applied to soils from grazing animals, and the application of compost and sewage was collected from publication by the Central Statistical Services (CSS) and literature. Traditionally crop residues are used for different purposes such as feed and construction, therefore only nitrogen content in below-ground biomass was considered to estimate N_2O emission from crop residues. The same activity data used to estimate direct

N_2O emission from managed soil was used to estimate indirect N_2O emission from atmospheric deposition of N and N leaching/runoff from managed soils. Annual fertilizer applied as limestone and dolomite was not available for all the inventory years.

2.16.4. Activity Data for The Forest and Other Land Use (FOLU)

The activity data for LULUCF was produced from land use statistics obtained from the Ethiopian Space Science and Geospatial Institute (SSGI) in geotiff forms. The data obtained in geotiff format for the years 2003, 2008 2013 and 2018 was used to produce land use and land use change maps and to characterize forest cover data per biomes. The original data from the SSGI categorized all the lands into seventeen land use classes. These seventeen land classes were aggregated into the six land use classes as per the IPCC 2006 Good Practice Guideline namely, Forest land, cropland, grassland, wetlands, settlements, and other lands. The aggregation of the data into six IPPC land classes was conducted for the years 2003, 2008, 2013, and 2018 based on the methodology described in Ethiopia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). To estimate annual land use and land use change data for the entire inventory years, i.e 1994-2018 formula for calculating annual forest change by Puyravaud, (2003) was used. Because there are country level emission factors for Forest land, a tier 2 approach was used. Thus, Forest land class was further categorized into four biomes namely: Acacia-Commiphora, Combretum- Terminalia, Dry Afromontane and Moist Afromontane. The data for each biome class for all inventory years was calculated through extraction of forest class from each monitoring period and then overlying each biome’s shapefiles on Forest Land use map and analyzing annual forest land estimation using the formula described by Puyravaud, (2003). Annual wood removal and Annual fuel wood removal was obtained from (FAO, 2010, 2015 and 2020). To estimate wood removal and fuelwood removal for forest biomes, its value was calculated by using the proportion of the biomes. Emission factors for different carbon pools sources (AGB, BGB, DW, SOC and Litter) were obtained from National Forest Inventory (NFI) (Table 2-29) (NFI, 2014), which mainly reflects country level circumstances and used for estimating CO_2 emission/removal in different carbon pools.

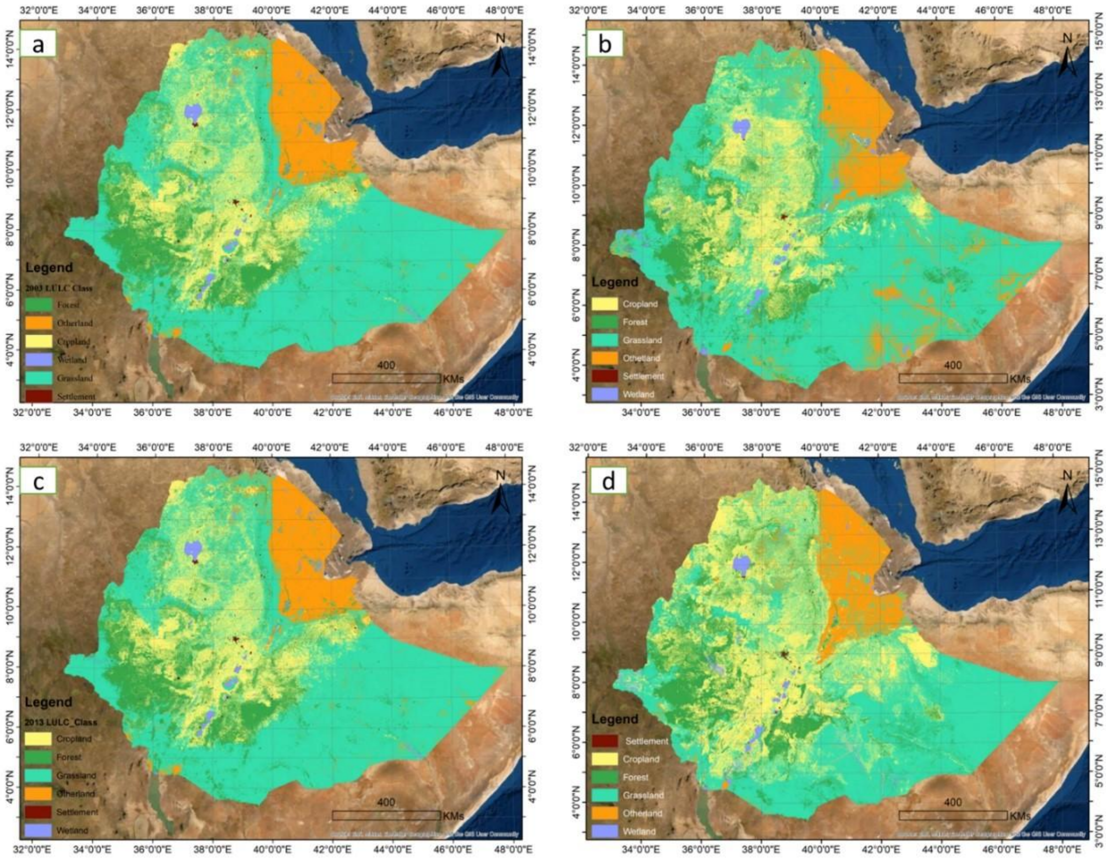


Figure 73 Land use categorized as IPPC`s six classes for the year a) 2003; b) 2008, c) 2013, and d) 2018Data Analysis Methods

2.16.5. Methane Emission from Enteric Fermentation in Cattle

To date, because of the scarcity of relevant data in Ethiopia, the Tier 1 approach is most commonly used to evaluate enteric methane emission from livestock. The IPCC Guidelines suggest that the uncertainty of enteric fermentation emission factors ranges from ±30% to ±50% for Tier 1 and ± 20% for Tier 2 approaches, respectively. Hence, the use of a Tier 2 approach may enable a decrease in the uncertainty of predicted enteric methane emission factors used in national GHG inventories and the TNC evaluation was implemented using the Tier 2 model recommended by IPCC 2006 for the cattle sub category. The 2006 IPCC model (equation 10.21) allows to approximate enteric methane emission factors (MEF, kg CH_4/head/year) which is the output variable (Table 2-25). To calculate gross energy intake (GE, MJ/d), net energy (NE, MJ/d) needed for different metabolic functions (i.e., maintenance, activity, growth, lactation, work and pregnancy) (Table 2-26) was predicted for each cattle subcategory using various formulas presented in the 2006 IPCC Guidelines p.10.21 Equation 10.16. The output variable is calculated based on input parameters, such as average live body weight (LW, kg), average daily weight gain (ADG, kg/day), milk production (Milk, kg/day), feeding situation, and digestible energy (DE, %). Finally, these parameters together with the methane (CH_4) conversion factor (Ym, %) enable calculation of net energy (NE, MJ/day), average daily feed intake (in terms of gross energy content, MJ/d) and the MEF (i.e., output) for each cattle sub-category. Country-specific emission factors were used for those cattle subcategory categories and division, while IPCC default EF (Emission Factor) values were utilized for sheep, goats, horses, camels, and mules/asses.

Table 43 Description of parameters for which country specific value was collected

Parameters	Description
Live Weight (kg)	Approximate weight of animal obtained through girth measurement
Mature weight (kg)	The body weight at which skeletal development is complete and used to define the feed and energy required for growth
Weight Gain (kg/day)	Used to estimate emissions associated with this weight change
Percent pregnant (%)	Used to calculate net energy requirement for pregnancy
Work hours per day (hours)	Used to estimate net energy for work specially for oxen
Milk Production (kg/head/year)	Used to calculate energy requirement for lactation
Fat content (%)	Average fat content of milk is required for lactating cows 4% for exotic & 5.5% for indigenous
Feeding situation	Used to estimate net energy requirement for activity
Digestible energy (%) in feed	Used to calculate CH_4 emission from enteric fermentation and nitrogen excretion frommanure
Protein (CP) content in feed	Used to calculate CH_4 emission from enteric fermentation and nitrogen excretion frommanure

Table 44 Coefficients for each livestock production system and cattle sub division

Parameter	IPCC Guideline section	Calculated value
Coefficients for Net Energy forMaintenance	2006 IPCC Guidelines p.10.16 Table 10.4	Net Energy for Maintenance (2006 IPCC Guidelines p.10.15 Equation 10.3)
Coefficients for Net Energy forActivity	2006 IPCC Guidelines p.10.17 Table 10.5	Net Energy for Activity (2006 IPCC Guidelines p.10.17 Equation 10.4)
Constants for pregnancy	2006 IPCC Guidelines p.10.20 Table 10.7	Net energy for pregnancy (2006 IPCC Guidelines p.10.20 Equation 10.13)
Coefficient for growth (C)	2006 IPCC Guidelines, p. 10.17 Equation 10.6	Net energy for growth (IPCC 2006 Guidelines,p.10.17Equation10.6)
Coefficient for work	2006 IPCC Guidelines, p. 10.19 Equation10.11	Net energy for work (IPCC 2006 Guidelines, p. 10.19 Equation 10.11)

Amount of milk produced, kg of milk day-1,	2006 IPCC Guidelines p.10.18 Equation10.8	Net energy for lactation (2006 IPCC Guidelines p.10.18 Equation 10.8) [MJ/DAY]
CH_4 conversion factor	2019 Refinement p. 10.48, Table 10.12	EF (kgCH_4/head/year) (2006 IPCC Guidelines p.10.31 Equation 10.21)

2.16.6. Methane Emission from The Manure Management

Livestock manure is a substantial source of methane (CH_4) and nitrous oxide (N_2O). The highest CH_4 emissions are typically associated with liquid-based manure management systems (MMS), where a large portion of manure decomposes anaerobically. In contrast, N_2O emissions vary significantly between individual MMS, and can also originate indirectly from nitrogen (N) that is lost during manure storage and handling (i.e. volatilization and leaching). The term “manure” in this report includes both the solid (dung) and liquid (urine) component of animal excreta, since the separation of liquid and solid excreta remains yet uncommon in Ethiopia. The methane (CH_4) and nitrous oxide (N_2O) emission from the cattle was based on the Intergovernmental Panel on Climate Change (IPCC) Tier 1 and Tier 2 calculations, respectively. The rest of the livestock categories both the methane (CH_4) and nitrous oxide (N_2O) emissions were based on the IPCC Tier 1 approaches.

For Tier 1 and Tier 2 manure EF calculations, the following data on climate and livestock characteristics were collected. Total livestock numbers per category (i.e. species, sex, age class, purpose) was obtained from the Ministry of Agriculture (MoA). Livestock categories are specified in Table 2-24. In addition, the type and contribution of different MMS as per the IPCC Table 10.18 definitions of manure management systems was obtained from MoA. The type and contribution of the different manure management system for adult pure exotic dairy cows of the commercial intensive system is presented in the Table 50.

Table 45 Manure management system for subdivision of dairy cows in 2018

Production system	Cattle subdivision	Management type	Percent
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% uncovered anaerobic lagoon	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% liquid slurry & pit storage, 1 month	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% liquid slurry & pit storage, 3 months	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% liquid slurry & pit storage, 4 months	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% liquid slurry & pit storage, 6 months	0%

Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% liquid slurry & pit storage, 12 months	5.6%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% deep bedding > 1 month	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% solid storage	59.46%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% dry lot	0%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% daily spread	2.91%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% composting	0.86%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% burned for fuel	28%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% biogas digester	3.48%
Commercial intensive system	Adult pure exotic dairy cows (3-10years)	MMS% pasture, range and paddock	0%

According to the IPCC Tier 1 approach, the default EF for CH_4 from cattle manure for the sub-Saharan Africa (SSA) is 1 kg CH_4 head-1 yr-1 (IPCC 2006, p. 10.39), assuming that cattle in SSA spend most their life grazing on pastures and that manure remains unused on the pasture, where it rapidly dries out and CH_4 production is low. The IPCC Tier 2 approach relies on two manure characteristics that affect the formation of CH_4 in manure: (1) the total amount of volatile solids (VS) that are excreted with the manure, and (2) the maximum or potential methane producing capacity of the manure itself (Bo).

2.16.7. Nitrous Oxide Emission from The Manure Management

There are both direct and indirect N_2O emissions from manure that occur after excretion. Indirect emissions of N_2O result from volatile N losses in the form of ammonia (NH_3) and nitric oxides (NO_x) that are lost during manure storage and management and deposited somewhere else, where those subsequently can lead to additional N_2O emissions. The Tier 2 calculations of N_2O emissions from manure management are based on the total amount of N excreted from all livestock categories that is handled in different MMS and which is multiplied with specific emission factors for each MMS. The same livestock categories and manure management classification annual N excretion rate per head (Nex) was calculated as per the IPCC 2019 Refinement, Equation 10.31, Calculation of N-intake daily N consumed/animal, Kg N/animal and day (IPCC 2019 Refinement, Equation 10.32), N retained for growth and milk production was calculated as per the IPCC 2019 Refinement, Equations 10.33 and 10.31. And finally Direct N_2O emission factor and Direct N_2O emissions per head was calculated.

2.16.8. Carbon Dioxide Emission from Forest and Other Land Use (FOLU)

The calculations of GHG emissions were carried out using suggested equations by IPPC (2006) (Table 2-28) using activity data, for each subcategory as an input. For the GHG inventory in LULUCF, generally, a Tier 1 approach was used except for Forest subsector. For Tier 1, the calculation was carried out using the activity data and country specific emission factors whenever available. If data for national circumstances is missing, IPCC default values were used from the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and IPCC's 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The forest sub-sector followed the Tier 2 approach thus, it was further categorized into four biomes and country specific emissions factors were used. The biomes include Acacia-Commiphora, Combretum-Terminalia, Dry Afromontane, and Moist Afromontane. Emission factors for different carbon pools (AGB, BGB, DW, SOC and Litter) were obtained from National Forest Inventory (NFI) (NFI, 2014), which mainly reflects the country's circumstance. The biomass gain-loss method was selected, as it applies to all tiers. The value for wood density was considered the average wood density suggested by (EFRLS, 2017).

Table 46 Formulas used for GHG Emission/removal for LULUC Subcategory

Carbon Pools	Equation Used
Annual Change in Carbon Stocks in Biomass in Land Remaining in A Particular Land-Use Category (Gain-Loss Method)	Equation 2.7, IPPC 2006
Annual Increase in Biomass Carbon Stocks Due to Biomass Increment in Land Remaining in The Same Land-Use Category	Equation 2.9, IPPC 2006
Average Annual Increment in Biomass	Equation 2.10, IPPC 2006
Annual Decrease in Carbon Stocks Due to Biomass Losses in Land Remaining in The Same Land-Use Category	Equation 2.11, IPPC 2006
Average Annual Increment in Biomass	
Annual Carbon Loss in Biomass of Wood Removals	Equation 2.12, IPPC 2006
Annual Carbon Loss in Biomass of Fuelwood Removal	Equation 2.13, IPPC 2006
Annual Decrease in Carbon Stocks in Biomass Due to Losses	Equations 2.11 To 2.14, IPPC 2006
Annual Change in Carbon Stocks in Dead Organic Matter	Equation 2.17, IPPC 2006
Annual Change in Carbon Stocks in Dead Wood or Litter (Gain- Loss Method)	Equation 2.17, IPPC 2006
Annual Change in Carbon Stocks in Dead Wood or Litter (Gain- Loss Method)	Equation 2.18, IPPC 2006
Annual Change in Carbon Stocks in Soils	Equation 2.24, IPPC 2006

Table 47 Emission factors for different carbon pools, Average wood density and growth level

Carbon pools, Wood density and growthstock	Emission Factors	Data Sources
AGC (t/ha)	70.1	NFI, 2018 (Weighted average of the four biomes
BGC (t/ha)	18.9	NFI, 2018 (Weighted average of the four biomes
DOC (t/ha)	1.7	NFI, 2018 (Weighted average of the four biomes
SOC (t/ha)	60.3	NFI, 2018 (Weighted average of the four biomes
Litter (t/ha)	4.1	NFI, 2018 (Weighted average of the four biomes
AGB in Forests (t/ha)	125	NFI, 2018
Growing Stock level (M3/ha)	128.3	NFI, 2018
Wood density	0.612 gcm-3.	EFRLS, 2017

2.16.9. Quality Assurance and Quality Control

The 2006 IPCC Guidelines recommends that quality control be exercised by comparing emission results using alternative approaches, comparing results and investigating anomalies. In view of that, in the course of activity data collection the quality assurance procedures were implemented through consistent checks to identify errors and omissions. Data was collected from the authentic sources and verifications were done. Activity data (land use change statistics) was obtained from the Environmental Protection Authority, the underlying spatial data was collected from Ethiopian Geo-Spatial Information Agency, and the figure was rechecked by an independent spatial data analyst. Similarly, all the data used for the AFOLU sector were checked for the error or omission. All calculations made during the exercise were done as per IPCC Guidelines using the IPCC GHG inventory software. The approved standardized procedures for emission calculations, measurements and documentations were applied. The inventory process was carried out under the close supervision of the project focal person, project manager and the client.

2.16.10. Uncertainty Analysis

The uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods. In LULUC analysis uncertainty might arise from wrong and low number of training data provided to GIS software, no or few ground truthing points, the resolution and quality of satellite images and so on. Moreover, discrepancy of acquired data from different sources is also a major source of uncertainty. In many government offices the culture of data management is not well progressed. Hence, it was difficult particularly to get long term historical data. Thus, this forces acquisitions of the same data from different sources, which ends up with wide discrepancies. For instance, there was 17% discrepancies in forest cover data that was obtained from satellite images and government offices and this might be attributed to many reasons as mentioned above. Uncertainty analysis indicated that feed digestibility and live weight (LW) for cattle, as well as the percentage of manure in different manure management systems across all production systems were the most influential variables. These are the key potential areas to reduce uncertainty and improve the accuracy of the GHG inventory in the future. Uncertainty of the enteric fermentation emission factors was ±18.0% in 2018. This compares well with the IPCC (2006) default uncertainty range for Tier 2 emission factors of ±20%. Uncertainty for total manure management methane emissions in 2018 was ±47.6%. Uncertainty for total manure management indirect N_2O emissions in 2018 was in the range of ±56.2 while Uncertainty for total manure management direct N_2O emissions was ±61.1% in 2018.

2.16.11. Enteric Fermentation EmissionFactor

As shown in Table 53 enteric CH_4 emission factors for adult multipurpose dairy cows were lower than those for adult pure exotic dairy cows. This difference in breed, feed intake and feed types, animal management, and body size is thought to have contributed to the lower enteric CH_4 emission factors for adult multipurpose dairy cows. Because foraging requires a lot of energy in the pastoralist/agro pastoralist and mixed agricultural livestocksystems,theothercattle'shigherCH_4emissionfactorscomparedto dairy cows may be the cause.

Table 48 Methane emission factor for each cattle subcategory

Enteric Fermentation CH_4 Emission Factor EF (kg CH_4/head/year) for the year 2018		
Dairy cows		
	Commercial intensive system	Smallholde r intensive system
Adult pure exotic dairy cows (3-10 years)	77.59	77.59
Adult pure exotic males 3-10 years	47.07	49.09
Pure exotic calves (<6 months) male & female	3.49	3.49
Pure exotic calves (6 m - < 1 yr) male & female	11.17	11.17
Pure exotic growing males (1 - < 3 years)	40.66	42.08
Pure exotic growing females (1 -< 3 years)	38.62	39.86
Other cattle		
	Pastoral & agro pastoral system	Mixed crop livestock system
Adult multipurpose cows >3 years	64.95	57.87
Adult males used for draught (3-10 years)	62.74	57.49
Adultmalesusedforbreeding&otherpurpose(>3-10years)	67.96	61.72

Pre-weaning calves < 6 months (male & female)	6.00	5.16
Post-weaning calves (6 m-1 yr.) male & female	18.33	14.62
Growing males 1-3years	57.15	53.87
Growing females 1-3years	45.54	41.39
Adult males (>3 years) smallholder feedlot		49.14
Adult males (>3 years) commercial feedlot		55.22

The emissions factors calculated for sheep, goats, horses, donkeys and poultry are the same as those found in the IPCC guidelines default tables (IPCC, 2006. Due to lack of country-specific activity data, Tier 1 approach had to be used for the other livestock sub-categories except the cattle.

Table 49 Emission factor for the other livestock subcategory

Type ofLivestock	Emission Factor Enteric Fermentation ($CH4$/head/yr.)
Sheep	5
Goats	5
Pigs	1
Rabbits	0
Asses	10
Camels	46
Poultry	0

2.16.12. Direct N_2O Emission Factor

Animal population data, activity data, and MMS data were used to compute the nitrous oxide emissions from the management of manure The Ministry of Agriculture offered information on manure management storage solutions for various types of cattle. As some MMS (such as liquid/slurry systems) are particularly sensitive to temperature fluctuations, a country average temperature of 20 ^{o}C was utilized as it is an average temperature for the range stated in the GHG guideline by the Ministry of Agriculture (MoA, 2015).

Table 50 Direct N2O emission factor

Manure Management System	Direct N_2O emission factor
EF_3 uncovered anaerobic lagoon	0
EF3 liquid slurry & pit storage, 1 month	0
EF3 liquid slurry & pit storage, 3 months	0
EF3 liquid slurry & pit storage, 4 months	0
EF3 liquid slurry & pit storage, 6 months	0

EF3 liquid slurry & pit storage, 12 months	0
EF3 deep bedding > 1 month	0
EF3 solid storage	0.01
EF3 dry lot	0.02
EF3 daily spread	0
EF3 composting	0.01
EF3 burned for fuel	0
EF3 biogas digester	0.0006
EF3 pasture, range and paddock	0.006

2.16.13. GHG Emissions and Removals in AFOLU Sector

2.16.13.1. Aggregated GHG Emissions in AFOLU Sector

The following graphs show trends in GHGs emissions and removal in CO_2eq from the AFOLU sector between 1994 to 2018. Throughout 1994 and 2018, the AFOLU sector released an average of 68,111.28 Gg CH_4, 4736.37 Gg N_2O, and 35,030.1 Gg CO_2 into the atmosphere, according to data compiled on the figures below. When emission/removal sources are evaluated, Land is by far the largest source of CH_4 and N_2O emissions whereas, Land is the primary source of CO_2 Emission/removal of the three GHGs (CH_4, N_2O and CO_2) from other sources are considerably low as shown on the figures below (Figure 77)

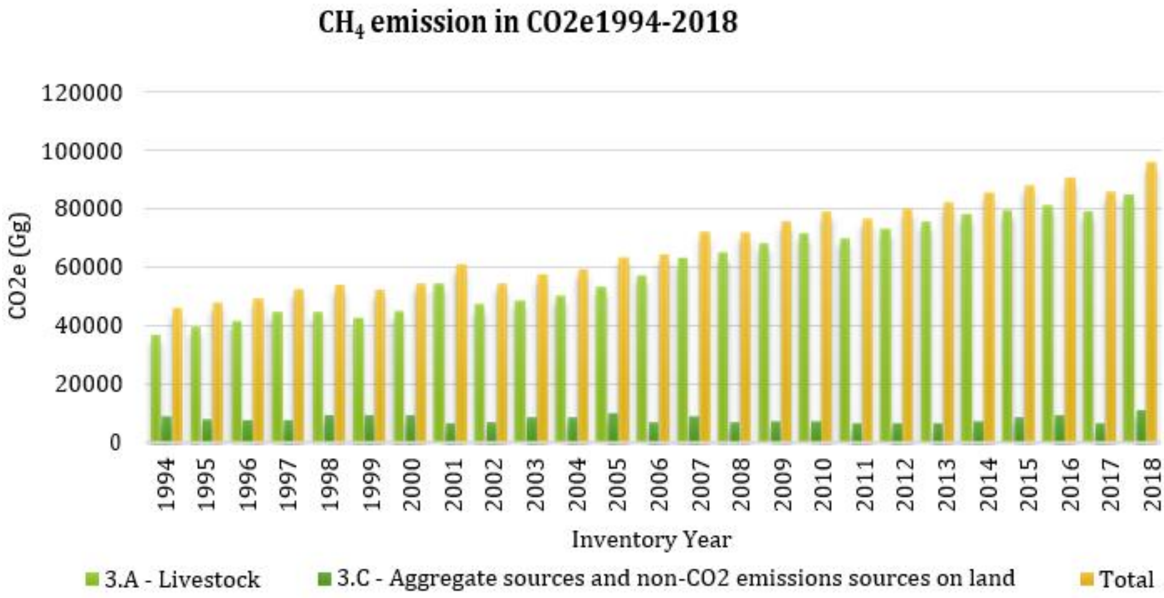


Figure 74 Methane emissions in CO2 eq by sources in AFOLU (1994-2018)

GHG emission has increased for the three gasses from different sources when compared to GHG levels in different base years. When comparing 2000, 2013, and 2018, to 1994, CH_4

emission increased by a constant 21.60%, 104.14%, and 129.19%, respectively from Livestock source. Similar to this, N_2O emission from the Livestock sub sector increased by 15.38%, 119.02%, and 141.75% during the aforementioned years compared to 1994. With the exception of CH_4, which decreased in 2013 compared to 1994, CH_4 and N_2O emissions have both increased from Aggregate sources (see Table 2-30). When compared to 1994, carbon dioxide (CO_2) removal fell by 5.22% in 2000, however CO_2 emissions rose by 418.92% and 522.61% in 2013 and 2018, respectively from Land source While CO_2 emissions from aggregate sources increased, it was consistently stored in "other" sources.

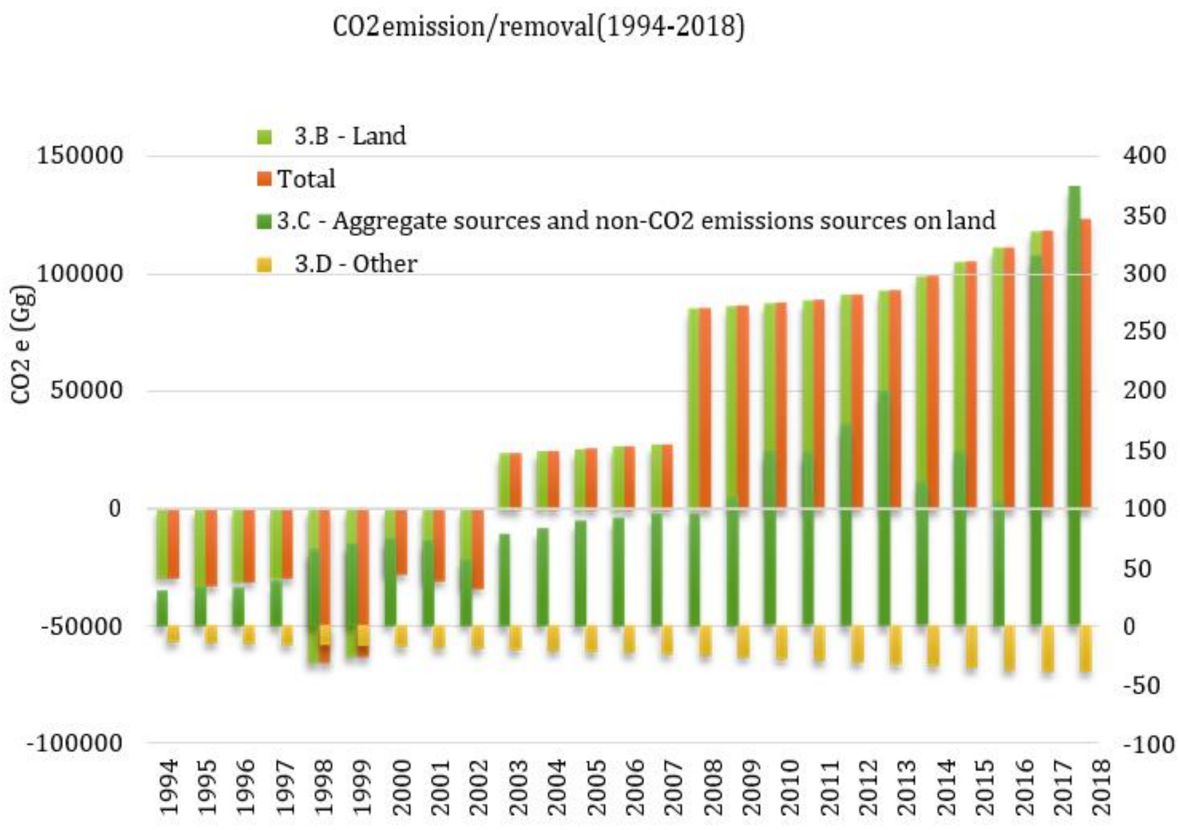


Figure 75 CO2 emission by sources in AFOLU (1994-2018)

Table 56 present the change in GHG emission and removals of the GHG inventory years.

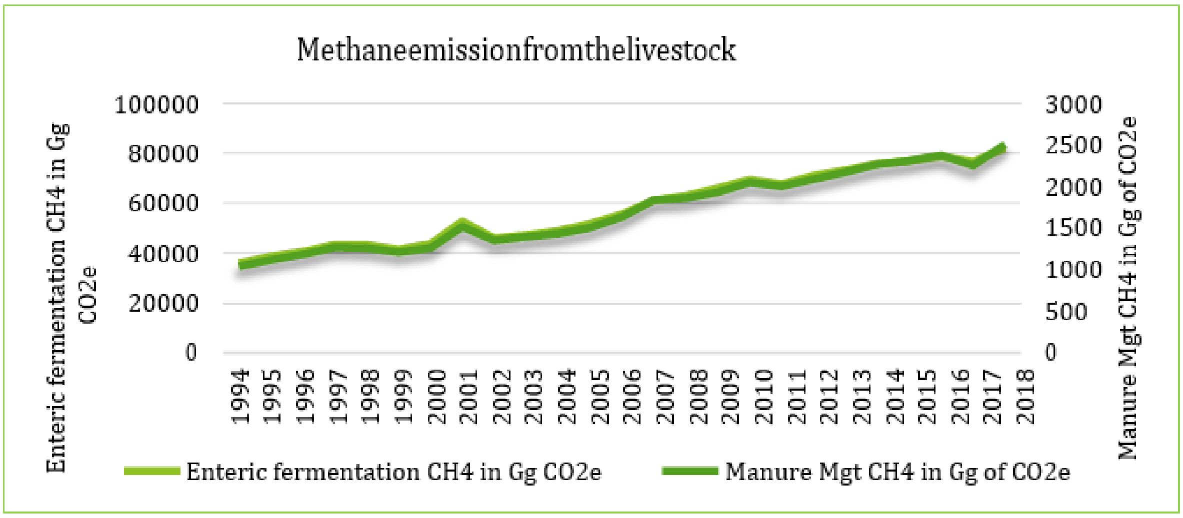
Table 51 Change in GHGs emission/removal.

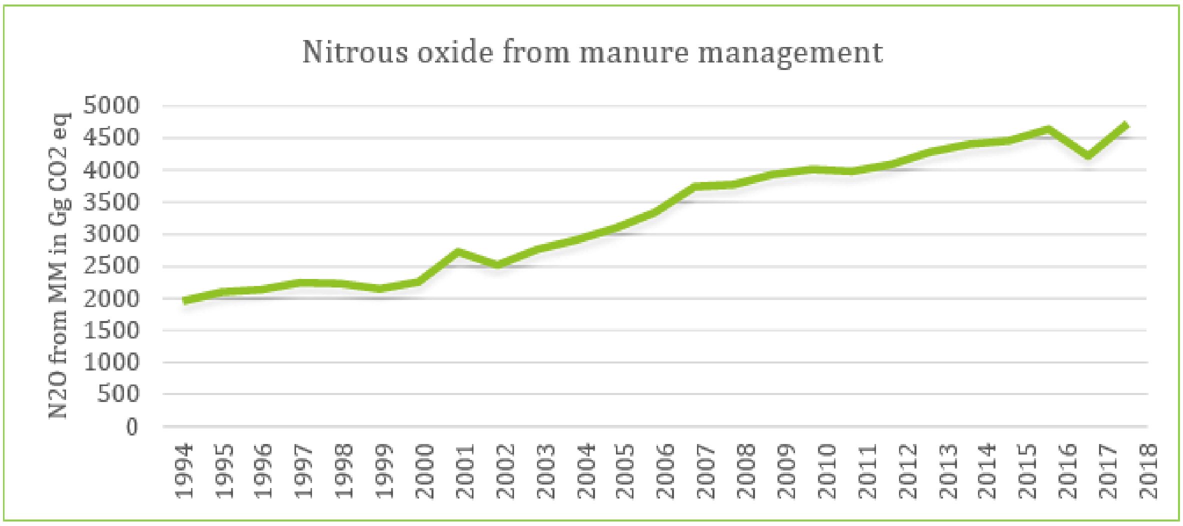
GHGs	Sources	1994	2000	% (1994Vs 2000)	2013	% (1994 Vs 2013)	2018	% (1994 Vs 2018)
CH_4	3.A - Livestock	37058.06	45062.77	21.60	75650.17	104.14	84932.86	129.19

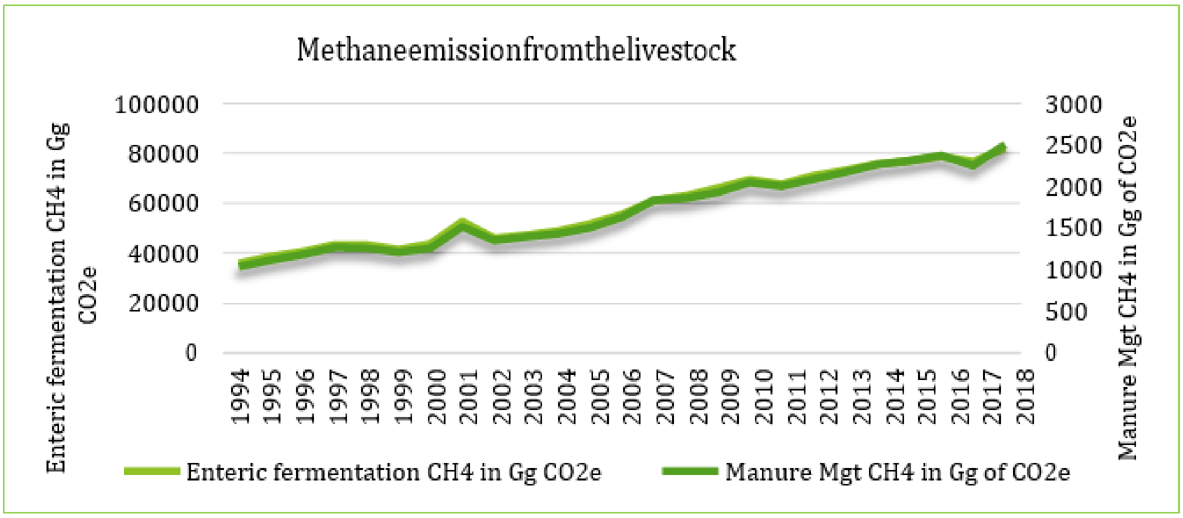
	3.C - Aggregate sources and non-CO_2 emissions sources onland	9094.28	9442.38	3.83	6770.97	- 25.55	11211.15	23.28
N_2O	3.A - Livestock	1953.27	2253.59	15.38	4278	119.02	4722.11	141.75
	3.C - Aggregate sources and non-CO_2 emissions sources onland	758.24	879.24	15.96	1558.97	105.60	1629.84	114.95
CO_2	3.B - Land	-29122	-27603	-5.22	92874.82	418.92	123072.9	522.61
	3.C - Aggregate sources and non-CO_2 emissions sources on land	29.18667	73.7455	152.67	199.925	584.99	374.1907	1182.06
	3.D - Other	-13.876	-17.9036	29.03	- 32.3908	133.43	- 39.0994	181.78

2.16.14. Livestock Emission by Gasses

Two significant greenhouse gasses (GHGs) released into the atmosphere by animals are methane (CH_4) and nitrous oxide (N_2O). Between 1994 and 2018, total CH_4 emissions from enteric fermentation and manure management increased by more than a factor of two, from 37,058.06 Gg CO_2e in 1994 to 84,932.86 Gg CO_2e in 2018. In 2018, enteric fermentation accounted for 97.03% of CH_4 emissions, while manure management accounted for 2.97%. In 2001, there was an increase in CH_4 emissions, which was caused by a large number of animals. The N_2O from manure management also rose, going from 1953.27 Gg CO_2e in 1994 to 4722.11 Gg CO_2e.


Methaneemissionfromthelivestock
Enteric fermentation CH4 in Gg CO2e
Manure Mgt CH4 in Gg of CO2e
100000
80000
60000
40000
20000
0
3000
2500
2000
1500
1000
500
0
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Enteric fermentation CH4 in Gg CO2e
Manure Mgt CH4 in Gg of CO2e


Nitrous oxide from manure management
N2O from MM in Gg CO2 eq
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018



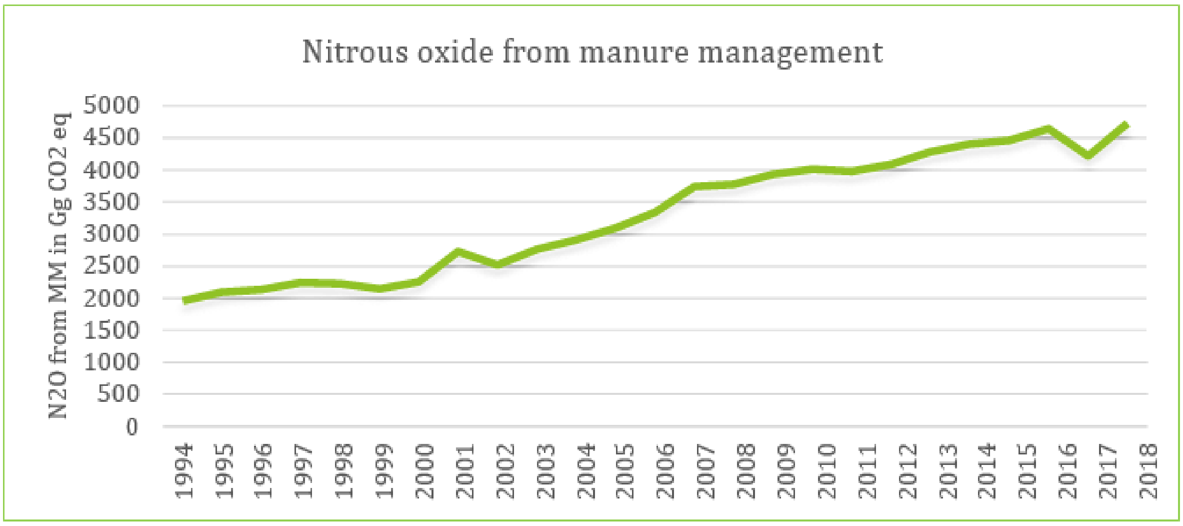


Figure 76 Emission by gases from the livestock

2.16.15. Methane and N_2O Emission by the Livestock Subcategory

Other cattle are the highest CH_4 emitters from enteric fermentation with an average of 49528.04 Gg CO_2 eq. (81.51%) while sheep are the second highest with an average of 2577.20 Gg CO_2 eq. (5.00%). Other contributors are goats, mule/asses, dairy cattle, camels and horses, with an average (percentage contribution) of 2329.28 Gg CO_2 eq. (4.39%), 801.94 Gg CO_2 eq. (3.04%), 803.56 Gg CO_2 eq. (2.52%), 851.56 Gg CO_2 eq.

(2.45%), and 736.43 Gg CO_2 eq. (1.05%), respectively. The trend analysis revealed increasing trends for all the livestock categories. About 63.40 % of the CH_4 emission from the manure management was contributed by other cattle, followed by Mule/Asses (11.94%), sheep (6.56%), goats (6.33%), camels (4.48%), horses (4.20%), dairy cows (1.87%) and poultry (1.18%).

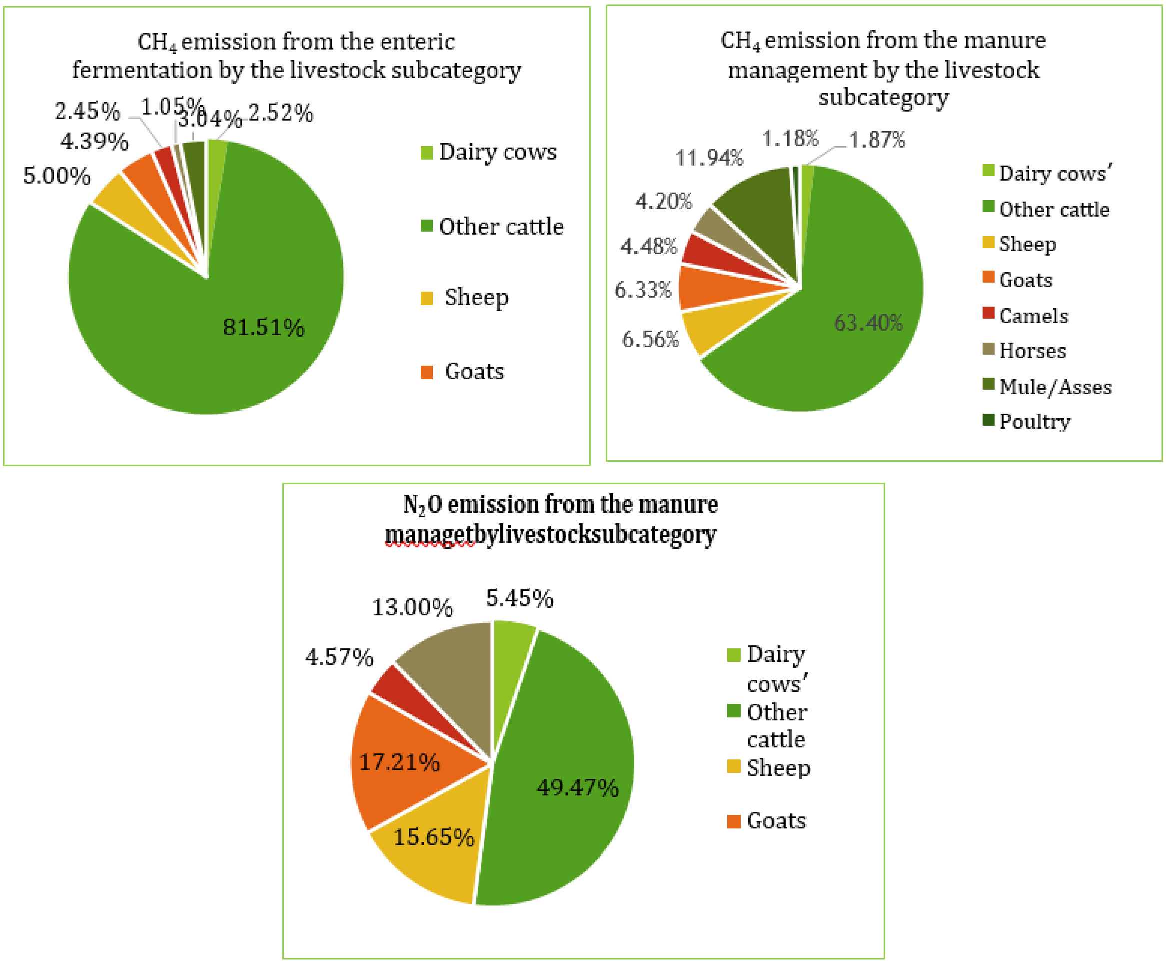


Figure 77 Methane and nitrous oxide emission by cattle category

The total estimated direct N_2O emissions from manure management added up to 4722.11 Gg CO_2 eq. in 2018. N_2O emissions from manure management were calculated for each livestock category, with other cattle contributing the most with an average of 1,788.52 Gg CO_2 eq., constituting 49.47% of the total N_2O emissions. The other main contributors are Goats and sheep with an average of 519.63 Gg CO_2 eq. (17.21%) and 468.95 Gg CO_2 eq. (15.65%), respectively.

2.16.16. Methane and Nitrous Oxide Emissions by Production Systems

Within livestock, cattle production systems can be broadly classified into Commercial intensive system, smallholder intensive system, pastoral and agro pastoral system, and mixed crop livestock system. CH_4 emission from enteric fermentation and manure management was high for mixed crop livestock systems (80.71%) followed by pastoral and agro-pastoral systems (17.03%) in 2018 which is attributed to the large cattle population of these two livestock production systems.

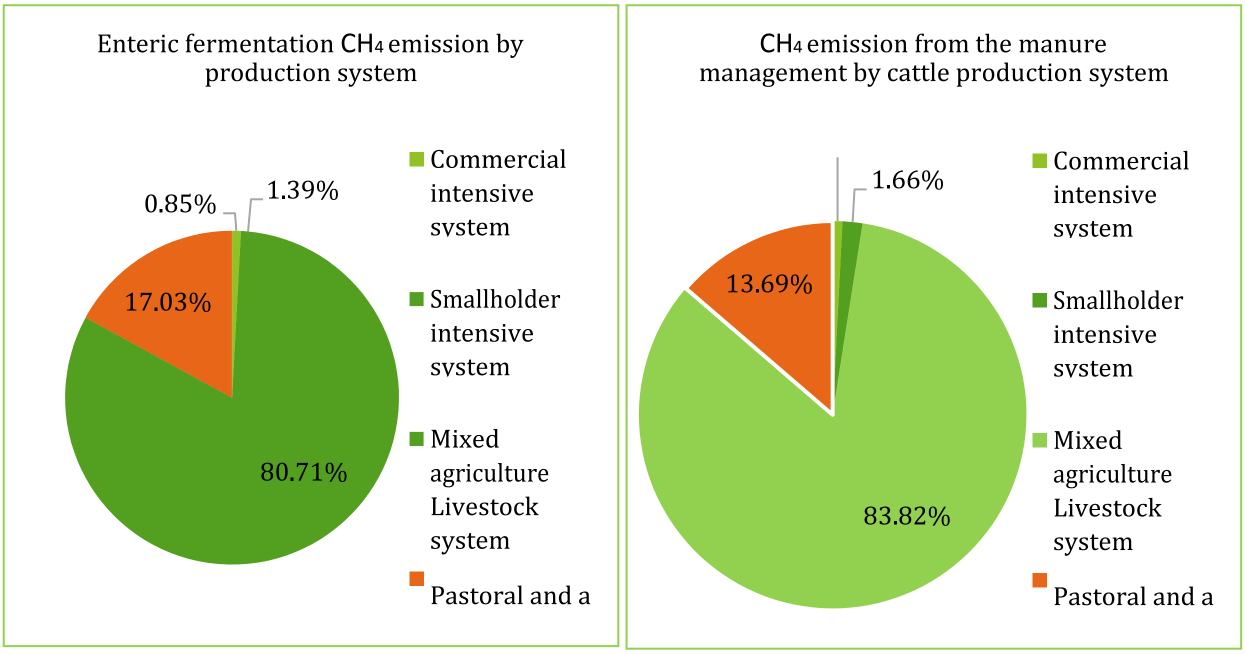


Figure 78 Methane from enteric fermentation and MM by production system

2.16.17. Recalculations of Livestock Sector Emission

The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Section 7.3) recommends the recalculation in cases of available data have changed, new methods become available and the capacity for inventory preparation has increased. The adoption of the country specific IPCC tier 2 methods for cattle, availability of data suitable for tier 2, and the inventory capacity developed by the country have triggered the recalculations. Emission from all sources exhibited an increment.

Table 52 GHG Emission Recalculations in Livestock Sectors

IPCC categ ory code	IPCC category	Greenhouse gas	1994 Year Estimate Ex0 (Gg CO_2 Eq.)	Recalculated value (Gg CO_2 Eq.)	2000 Year Estimate Ex0 (Gg CO_2 Eq.)	Recalculated value (Gg CO_2 Eq.)	2013 Year Estimate Ext (Gg CO_2 Eq.)	Recalculated value (Gg CO_2 Eq.)
3.A.1	Enteric Fermentati on	CH_4	27914.75	36014.9	30693.97	43797.62	52088.32	73471.36
3.A.2	Manure Managem ent	N_2O	7,334.886	1953.27	6365.59	2253.59	12037.162	4278
3.A.2	Manure Managem	CH_4		1043.16	1139.08	1523.99	2035.37	2178.81

	ent							

2.16.18. GHG Emission/removal in Land Use Land Use Change and Forest

Carbon dioxide emissions/removal from categories of Land, Aggregate source (i.e., CO_2 emission from Urea application) and Other (i.e., CO_2 emission/removal from Harvested wood products) is discussed here. Overall, the land category consistently served as a sink sequestering CO_2 between 1994-2002. However, this trend has changed into emission since 2003 and continued until the end of the inventory year (**Error! Reference source not found.**). Sub category of aggregate sources on land, contributed inconsiderably with average value of 113.43 Gg of CO_2 emission between 1994-2018. "Other" sub category removed an average of -23.11 Gg of CO_2 with harvested wood products with the same inventory year.

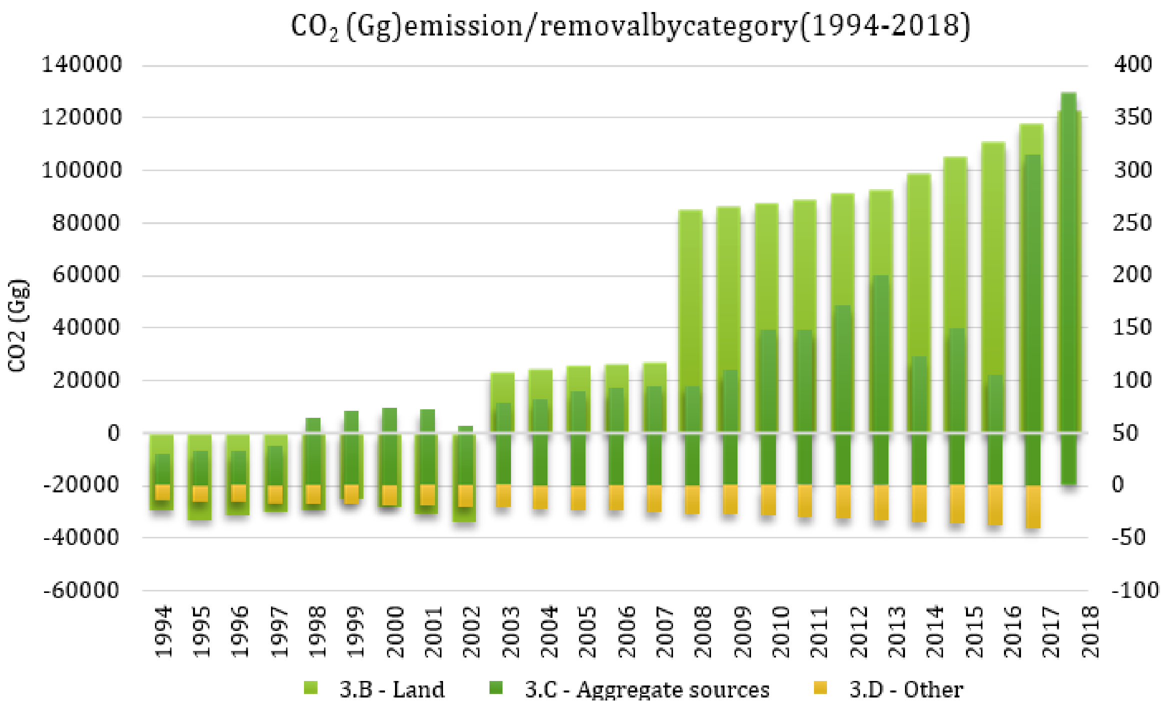


Figure 79 CO2 emission from 1994-2018 by Category

2.16.19. GHG Emission fromLand

Land Use Land Use Change & Forestry (LULUF) has been both a source and sink of CO_2 emission. Data in Figure 83 shows that the subsector served as a sink between 1994 and 2002 with average sequestration of -38043.29 CO_2 Gg. The forest land remaining forest land and land converted to forest land played a role as being a sink for CO_2. Since 2003, the LULUCF has been a source of CO_2 emission until the end of the inventory year, 2018 with average emission of 75995.23 Gg CO_2. Cropland and grassland as well as land conversion into cropland and grassland considerably contributed to CO_2 emissions between 2003 and 2018.

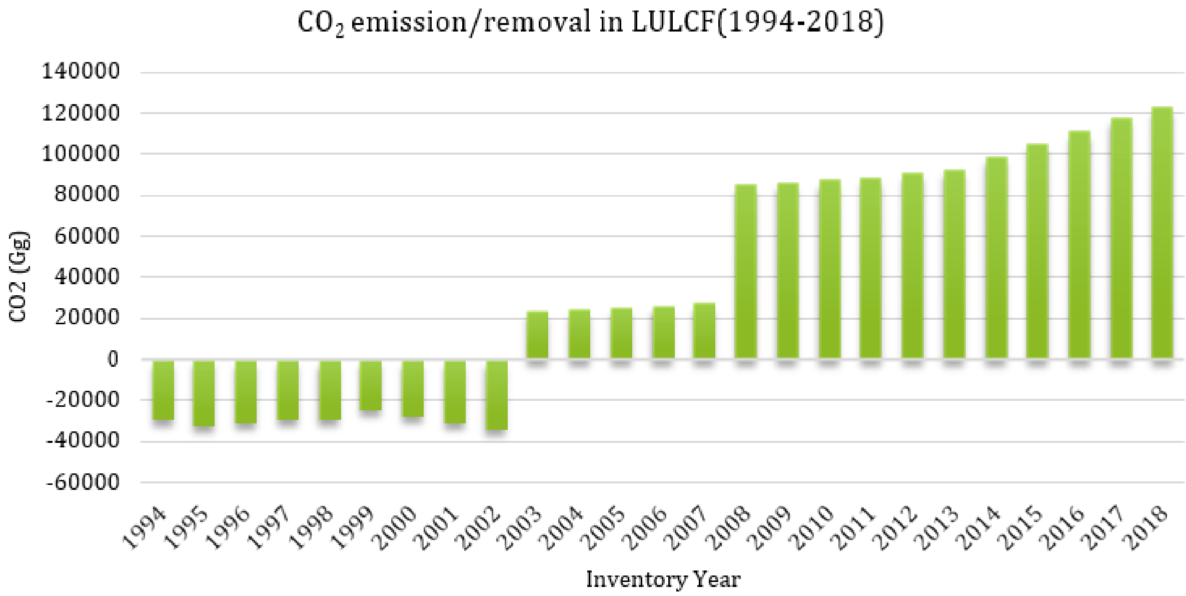


Figure 80 CO2 emission from 1994-2018 in the LULUCF sector

Figure 85 CO2 emission/removal by land class (1994-2018) Comparing CO2 emission between 2013 and 2018, which is the inventory end year, informed that Grassland and Cropland continue to be a major contributor of CO2 Emission. CO_2 emission by land class is presented. Grassland and Cropland clearly are the highest CO_2 emitters with average value of 70,696.9 and 37,579.6 Gg respectively between 1994-2018. The emissions from Grassland and cropland mainly come at the expense of forest land converted to Crop (farmland) and grazing land showing the extent of deforestation and forest degradation. Forest land is the main CO_2 remover with an average sequestration of -67,068.85 Gg of CO_2 throughout the inventory years. The remaining land classes (Wetland, settlement and other land) have been both sources and sinks of CO_2 emission throughout the inventory year. Many factors could be behind emissions from Grassland and Forest Land, obviously deforestation plays a key role that might have been caused by introduction of different land use policy and strategies in the country. Ethiopia's Agricultural Development Led Industrialization (ADLI) adopted in 1994. The policy has promoted intensive farming practices and cropland expansion by providing extension and credit programs to small-scale farmers. The policy in addition encouraged agricultural investment which promoted agricultural expansion that may also have encouraged further deforestation and intensification in different regions (Gebreselassie, 2006). Such causes of deforestation have been also reported in many tropical regions (Geist & Lambin, 2002; Lambin et al., 2003; MA, 2005). This doesn't mean that there were no forest and land restoration efforts in different parts of Ethiopia. For instance, research done in some parts of Ethiopia suggest that forest cover has increased in Northern and Northwest Ethiopia since 1961 (Bewket, 2002, Crummey, 1998, Meire et al., 2013, and Teka et al., 2014). But still, most researchers also reported forest decline in many parts of Ethiopia, and Millennium Assessment (MA, 2005) considered Ethiopia as one of the 29 countries which lost > 90% of its original forest cover. After ADLI, many subsequent development programs have been introduced between 2010-2015 and these include Poverty Reduction Strategy

Program, the PASDEP, the Growth, and Development Program, the GTP, and Climate Resilience and Green Economy Strategy, CRGE. Many of the programs have emphasized the expansion of large-scale commercial farming and agro-industries, which most likely have significant impacts on the forestry sector of the country (Bekele et al., 2015). For instance, it was reported in 2012 and 2013 that 3.31 million ha of land a large portion of its forestland was identified and transferred to the federal land bank for potential transfer to investors. In the first 3 years of the planning period of GTP, a total of 473 thousand ha of land was reportedly transferred to investors (FDRE, 2014). In general, deforestation caused by the political economy and many other drivers is responsible for much of the CO_2 emissions increasing since the inventory year 2003.

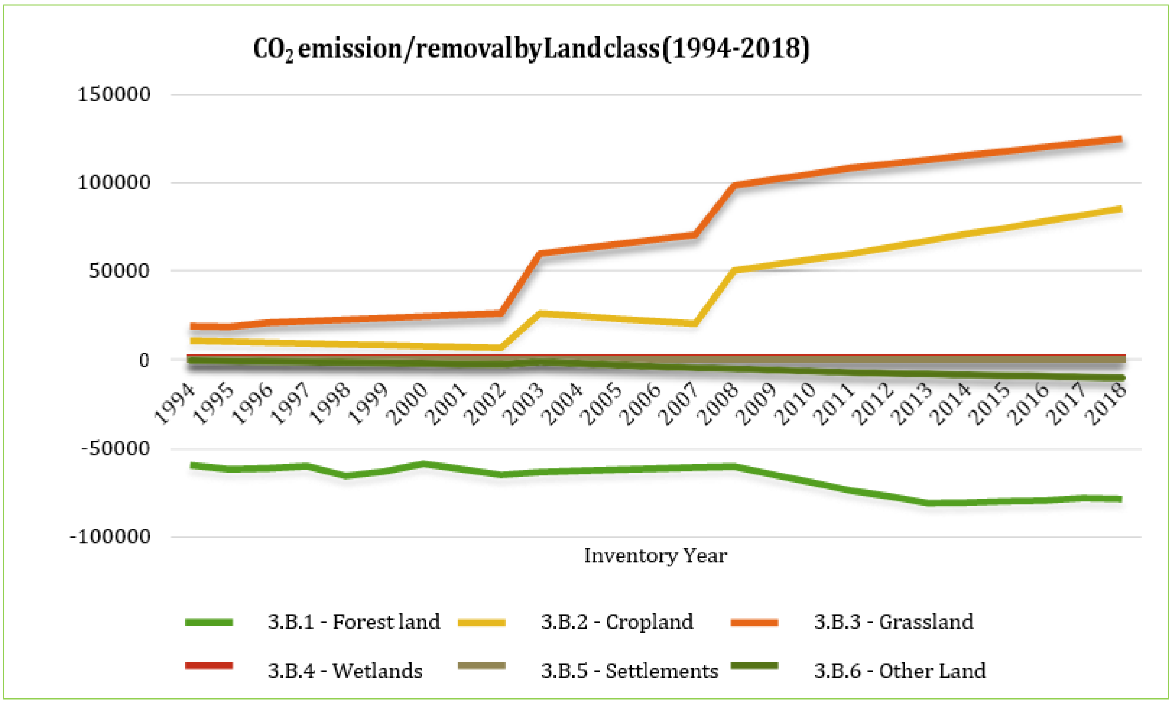


Figure 81 CO2 emission/removal by land class (1994-2018)

Figure 2-82: CO_2 emission/removal by land class (1994-2018)Comparing CO_2 emission between 2013 and 2018, which is the inventory end year, informed that Grassland and Cropland continue to be a major contributor of CO_2 Emission

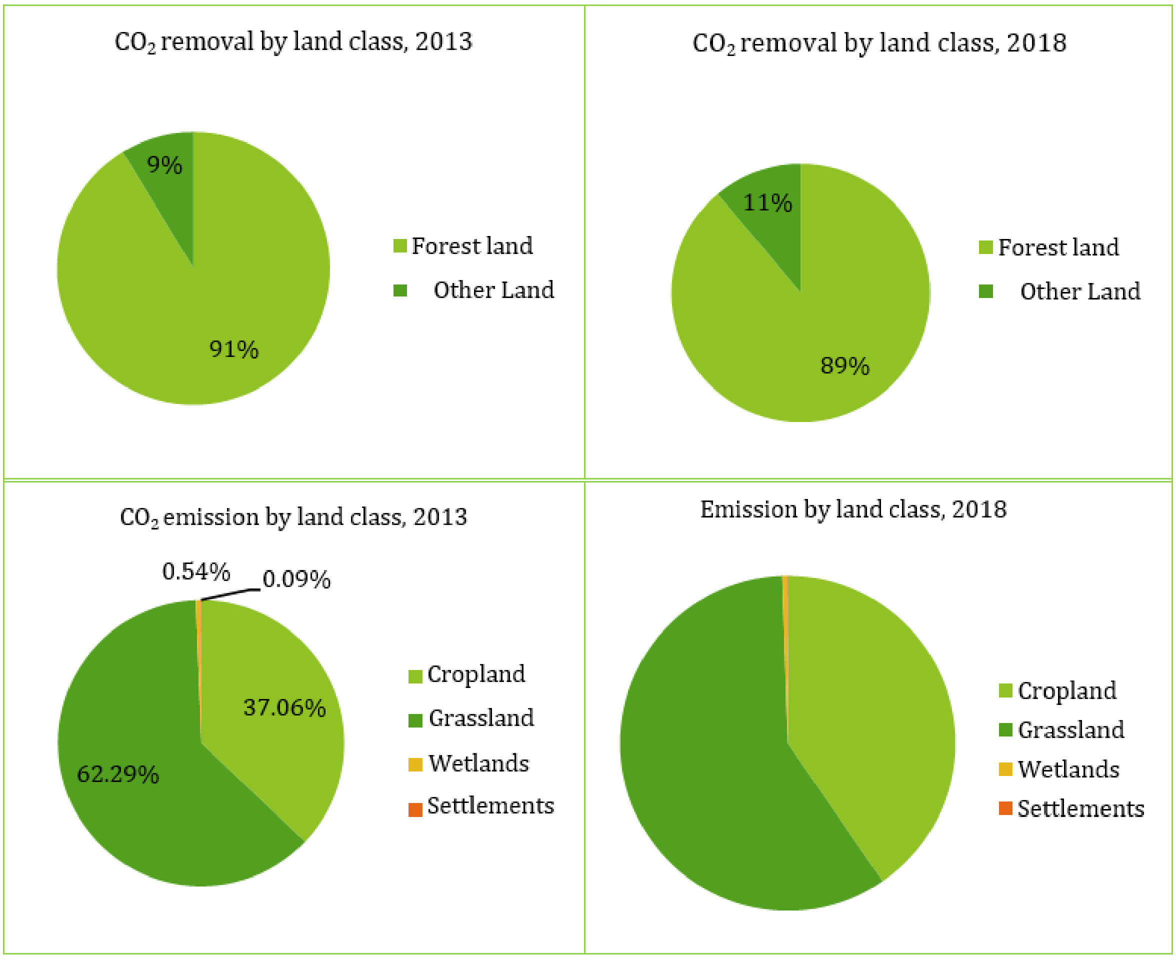


Figure 83 CO2 emissions/removal comparison between 2013 and 2018

2013 from Grassland and 18,268.1 Gg more of CO_2 from Crop land. That is an increase of 90.5%, 78.6% respectively. The highest increment in grassland comes from conversion of Grassland to Cropland due to farmland shortage as the population keeps increasing. Forest land was a sink for CO_2 in 2013, however it declined by 2 % in 2018, which is equivalent to 2228.4 Gg of CO_2 emission. Other land classes contributed in removal of CO_2 , though insignificant. Recalculating CO_2 emission/removal of 1994, 2000, and 2013 with that of the Second National Communication showed that there are inconsistencies in CO_2 emission/removal estimation Table 58. Estimation of CO_2 in Forest land shows removal of the gas with almost similar values for 1994 inventory. Carbon dioxide (CO_2) estimation of the years 2000 and 2013 from forest land shows a big difference. In Cropland as well large differences in CO_2 estimation are seen in all years. The same is true in CO_2 estimation in Grassland for the inventory year 1994, 2000 and 2013. This might come from inconsistency in data sources in government organizations as there is no central database where data is stored and can be fetched. And also, the method used for estimating land use and land use change in the two national communications might cause the discrepancies.

Table 53 CO2 emission/removal recalculation

IPCC category code	3.B	3.B.1	3.B.2	3.B.3
IPPC Category	Land	Forest land	Cropland	Grassland
GHG	CO_2	CO_2	CO_2	CO_2
1994 Year Estimate Ex0 (Gg CO_2 Eq.)	-28346.1	-29109.3	89703.88	172841
1994 Recalculated value	-29122	-59509.9	10807.87	19113.02
Difference in %	2.74	104.44	-87.95	-88.94
2000 Year Estimate Ex0 (Gg CO_2 Eq.)	102648.7	-93845	88008.97	108122.4
2000 Recalculated value	-27603	-58688.8	7851.66	24443.04
Difference in %	-126.89	-37.46	-91.08	-77.39
2013 Year Estimate Ex0 (Gg CO_2 Eq.)	32596.47	-86981.4	75582.58	41403.88
2013 Recalculated value	92874.82	-80873.5	67260.44	113034.8
Difference in %	184.92	-7.02	-11.01	173.01

2.16.20. Emissions from Biomass Burning

Methane emissions come from burning biomass, whether it's uncontrolled or under control. Emissions from burning biomass are graphed from 1994 to 2018 in Figure 88 below. Overall, it appears that the trend of emissions from burning biomass is increasingly causing CH_4 emissions. The emissions from Grassland, which is regulated biomass burning, were lowest in 2001 at 268.8 Gg CH_4 or 6714.88 Gg of CO_2e and highest in 2018 at 447.3 Gg CH_4 or 11,200 Gg CO_2e. In Ethiopia, deliberate burning of grassland vegetation is a frequent technique to encourage the sprouting of new vegetation for cattle grazing. In several years of inventory, the amount of CH_4 emissions from wild biomass burning from forest land was less than 1 Gg.

The year 2000 saw the largest emission on record for forest land, which was 36.6 Gg of CH_4 or 913.73 Gg of CO_2e. This outcome is consistent with the findings of the reports of Goldammer (2000) and SCBD (2001), which show that Ethiopia had its first significant fires since 1984 in March 2000. With an estimated loss of 53,000 acres, the fire primarily destroyed moist tropical forests and afro-montane forests. Another key factor in lowland forest fires is the use of fire for hunting and tsetse fly control. These are also common causes of uncontrolled wildfire in forest land. In the highlands, forest land is burned to clear it and make room for agricultural usage. Another reason for forest fires is smoking out wild bees to collect honey (IFFN, 2001; Goldammer and de Ronde, 2004).

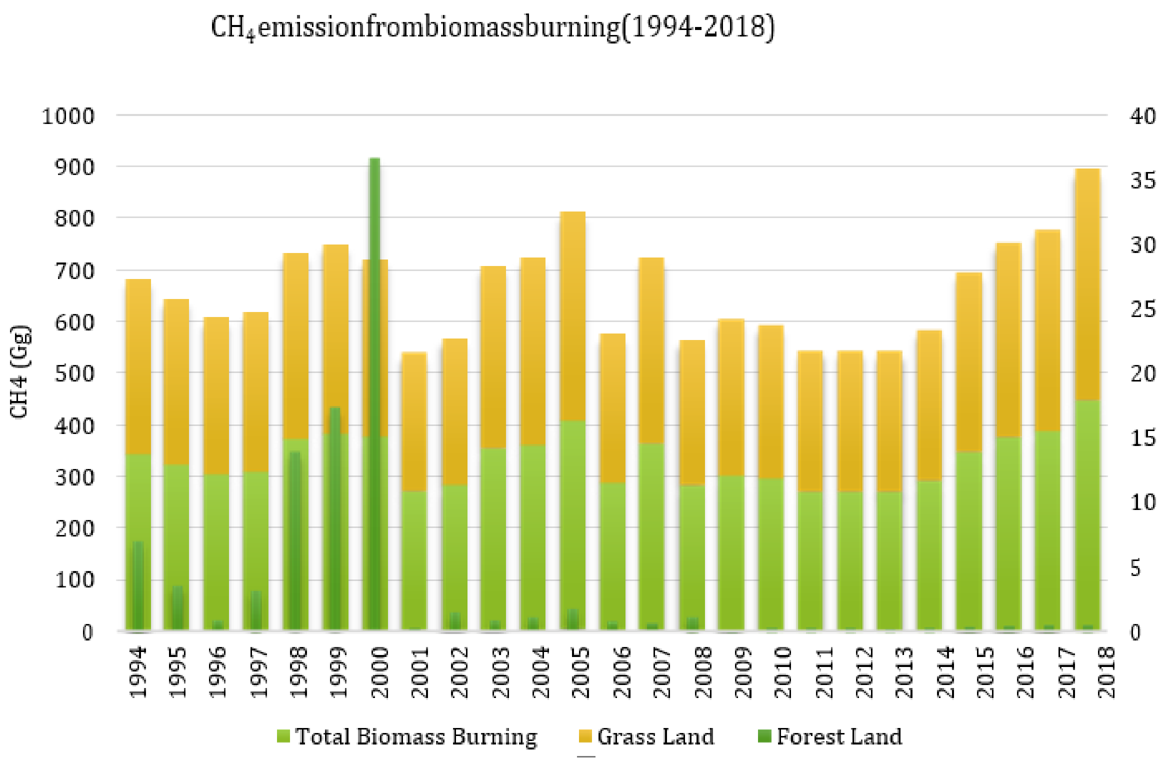


Figure 84 CH4 Emission from Biomass Burning in Forest and Grassland from 1994-2018

2.16.21. Urea

The use of nitrogen (N) fertilizer has been identified as a possible important source of nitrous oxide (N_2O) emission from agricultural soils, and urea is the main form of N fertilizer used in Ethiopia. The urea consumption of the country increased from 39,800 tons in 1994 to 510,260 tons in 2018 growing at an average annual rate of 13.34%). On average the urea application/consumption from 1994 to 2018 was 257,418.3 tons or 233,526 Mg per year. Emission from urea in agriculture was estimated to be 374.19 Gg of CO_2 eq. in 2018 (Figure 88)

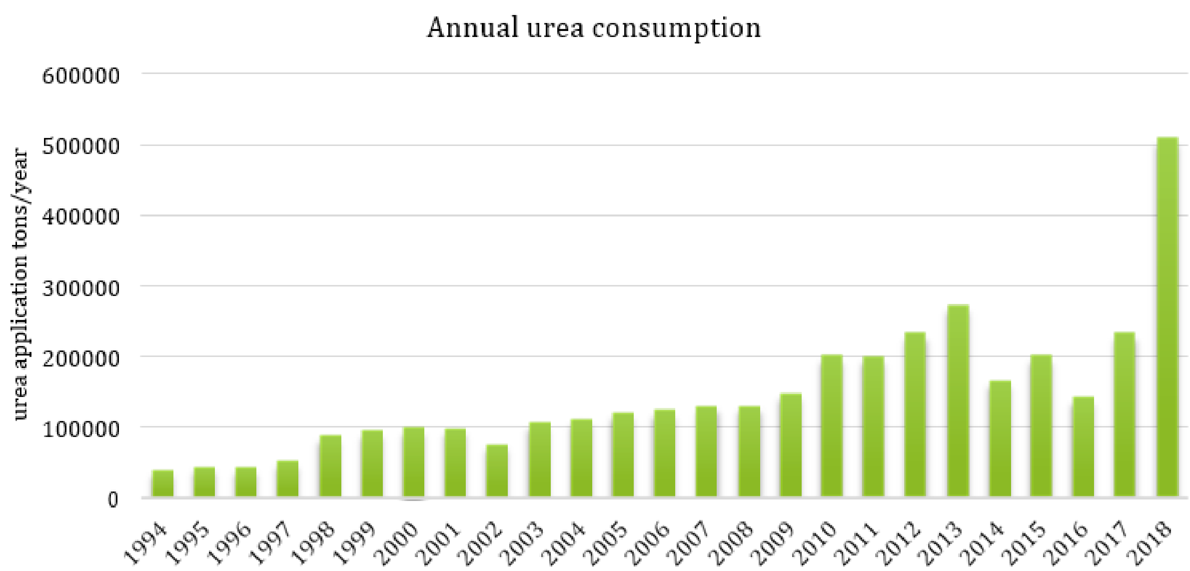


Figure 85 Annual urea consumption

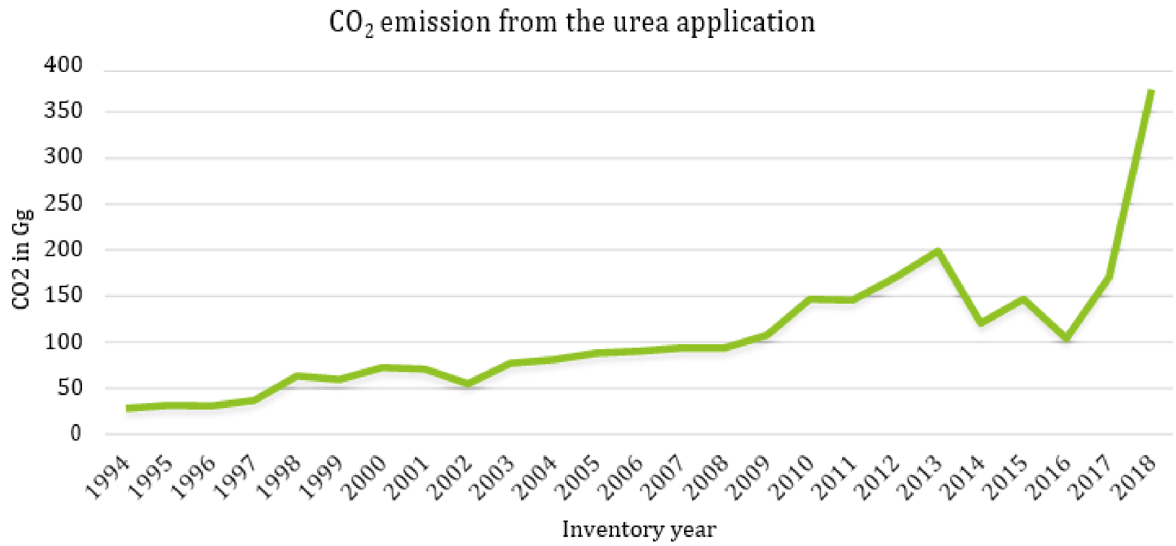


Figure 86 Carbon dioxide emission from urea

2.16.22. Carbon dioxide emission from urea Liming

Adding carbonates in the form of limes, such as calcitic limestone (CaCO3) or dolomite ($CaMg(CO_3)_2$, decreases soil acidity and enhances plant development, which releases CO_2. In Ethiopia, lime application only recently began. In 2016, the MoA began putting lime on the soil. In 2016, 2017, and 2018, a total of 14,350ha, 11,996ha, and 23,250 ha of land received lime treatment. Although the amount used varies on how acidic the soil is, MoA uses an average of 30kg per ha. In 2016, 2017, and 2018, the emission due to the application of lime was 0.19 Gg CO_2, 0.16 Gg CO_2, and 0.30 Gg CO_2. Direct and Indirect Nitrous Oxide Emission

In Figure 90, Direct and indirect emissions of N_2O from managed soil and manure management are mostly caused by organic nitrogen applied as manure, urine, and dung that is left behind by grazing animals on pasture, range, and paddock. In 1994, the managed soil produced direct N_2O emissions of 292.13 Gg of CO_2e and 606.5 Gg of CO_2e in 2018. Indirect N_2O emissions from the managed soil were 124.15 Gg of CO_2e in 1994 and 204.73 Gg of CO_2e in 2018. Indirect CO_2 emissions from manure management increased from 341.96 Gg in 1994 to 818.61 Gg in 2018.

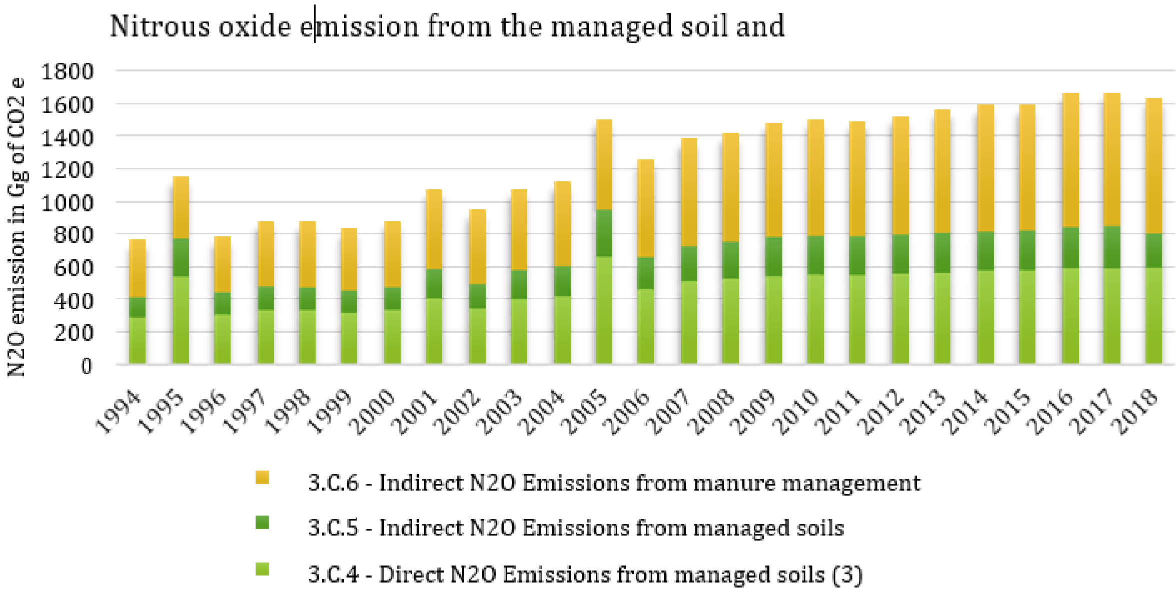


Figure 87 Direct and indirect N2O emission from the managed soil and manure management

2.16.23. Gaps and Future Potential Improvements for AFOLU Sector GHG Inventory

Major adjustments needed to improve GHG estimates in the AFOLU sector in Ethiopia are as follows:

- Currently LULUCF activity data was generated from the 2003, 2008, 2013 and 2018 land use maps for the entire country which was obtained from Ethiopian Geo- Spatial Information Agency. Interpolation and extrapolation techniques were used to generate the activity data for the missing period which could lead to inaccuracy to a certain level. The new approach which depends on the training exercise and which uses Bing Maps and Google Earth Engines could more accurately track the LULUCF.

- The IPCC GHG inventory software categorizes the entire country under one climate zone although the country has diverse agro ecology.

- Although the country has diverse soil types the default value was used for the quantification. The future inventory should use geographically explicit soil data.

- Improving the estimation of enteric fermentation of major livestock subcategories like sheep, goats, horses, camels, and mule/asses should be upgraded from Tier 1 to Tier 2. This exercise would require a further breakdown of livestock population data per production type, sex and age. There should be intensive activity data acquisition per livestock sub-categories.

- The TNC applied IPCC tier 2 to quantify CH_4 emission from the enteric fermentation, nitrous oxide from the manure management for cattle subcategory. Similarly, the GHG quantification capacity should develop and shift from the default method to the upper tiers for all the AFOLU subsectors.

2.17. Waste sector

Ethiopia is one of the fastest growing countries in sub-Saharan Africa and the second most populous country in Africa. There is also a rapid rate of industrialization coupled with change of lifestyle of the people which leads to generating huge volumes of solid waste and wastewater from domestic and industrial sources. The rate of MSW in Ethiopia is estimated to be 6 million tons per year in 2015 and is predicted to increase to 10 million tons per year by 2030 and 18 million tons per year by 2050 (Hirpe and Yeom, 2021; Kaza *et al.*, 2018). The solid waste generation rate was estimated to be 0.45 kg/capita/day in Addis Ababa and an average of about 0.32 kg/capita/day, in the major cities. The volume of solid waste generated in Addis Ababa alone was reported in the range of 3.2 to 3.7 million M^3 in the year between 2016 and 2020**.**

The recent report of the world bank group showed that the average per capita solid waste generation rate of Ethiopia is estimated to be 0.18 kg/capita/day (Kaza et al.,2018). The IPCC (2019) default per capita solid waste generation rate for Eastern Africa is determined to be 0.79 kg/capita/day. On the other hand, the results found in a study conducted at 48 different cities/towns in Ethiopia indicated that the average per capita solid waste generation rate is 0.31 kg/capita/day (MoUDC, 2020). According to the world bank group report by Kaza et al. (2018) about 57% of the generated solid waste is collected in Ethiopia, while the remaining is dumped openly resulting in potential adverse impacts on the public health, surrounding environment and quality of urban life (Diriba and Meng, 2021), while the MoUDC (2020) report showed that only 40% of the generated waste are collected in the country.

There is also a growing rate of wastewater generation from both domestic sources and industries in the urban areas of the country. The sources for industrial wastes are textile and garment industries, tanning industries, beverage industries and industrial parks. Most of the industries in the country discharge their effluents to the surrounding environment without adequate treatment.

2.17.1. Methodological Framework

The waste sector constitutes emissions originated from the disposal and treatment of solid and liquid waste, and includes CH_4, N_2O, and CO_2 emissions from four subsectors, according to the IPCC 2006 methodology: Solid Waste Disposal (4.A), Biological Treatment of Solid Waste (4.B), Incineration and Open Burning of Waste (4.C), Wastewater Treatment and Discharge (4.D), and Other Waste including clinical and hazardous waste (4.E). Waste sector greenhouse gas (GHG) emission inventory was estimated based on IPCC (2006) guideline for emission inventory. The estimation was made using the IPCC guideline Tier 1 method due to lack of country specific data. Expert judgment was also made for estimation of country specific solid waste generation rate and domestic waste fraction of degree of utilization. The Global Warming Potentials (GWPs) from the IPCC fourth Assessment Report (AR4) were applied in converting GHG from units of mass to CO_2-eq. The computation was made using IPCC inventory software (version 2.69). The GHG emission inventory report was prepared according to the UNFCCC convention in compliance with the IPCC 2006 guidelines.

2.17.2. Waste Sector's Emission Estimation

The volume of municipal solid waste generation and methane emission for urban and semi-urban areas was estimated using solid waste generation rate (113.2kg/capita/year) from Ministry of Urban Development and Construction (2020) and urban population data from 1950 to 2018 (UNDP, 2018). The degradable organic carbon (DOC) values used for different types of organic waste components are indicated in. The default value for degradable organic carbon fraction was 0.5 while for-methane recovery and oxidation, the default value of R = zero was used (2006 IPCC Guidelines (Vol. 5, Chapter 3). The GHG emission was estimated according to IPCC (2006) guidelines using the Tier 1 First Order Decay (FOD) method. The FOD equations 3.2 to 3.6 (2006 IPCC Guideline, Vol 5, Chapter 3) were used to estimate the methane emissions. Methane emission from unmanaged shallow (<5m waste) and uncategorized was computed using default Methane Correction Factor (MCF) of 0.4 and 0.6, respectively (IPCC, 2007). Table 59

Table 54 Composition of municipal solid wastes and corresponding DOC value

Typeofmunicipalsolidwaste	Composition (%)	DOC Content of wet waste (%)	Methane Generation Rate Constant (k)
Food waste	53.9	15	0.085
Garden waste	4.5	20	0.065
Paper/cardboard	7.7	43	0.045
Wood	7.0	40	0.025
Textiles	1.7	24	0.045
Nappies	0.7	24	0.065
Other waste including (Plastic, rubber,leather,glassandmetal)	24.5		-
Sewage sludge		5	0.085
Industrial waste		15	0.065

Source: IPCC 2006, Volume 5, Chapter 2, Table 2.3 and 2.4; Ethiopia's SNC to the UNFCCC, 2015,

Table 55 Waste Model IPCC Default Emission Factors and Coefficients

Default IPCC parameter	Default values used in the model
Methane correction factor (MCF)	0.4 (unmanaged shallow)
	0.6 (uncategorized SWDS)
Methane recovery factor	0
Fraction of DOCdissimilated	0.5
Methane generation rate constants (k) (yr^{-1})	0.085 (food waste, sewage sludge)
Default for Eastern Africa and Dry Tropical climate zone	0.065 (gardens, disposable nappies)
	0.025 (wood and straw)
Delay time (months)	6
Fraction of methane (F) in developed gas	0.5

Source: IPCC 2006, Volume 5, Chapter 3, Tables 3.1 and 3.3

2.17.3. Incineration and Open Burning of Waste

The emissions from waste incineration were not considered due to lack of activity data while GHG emissions from open burning was calculated with the assumption that 50% of the solid waste is managed using uncontrolled burning practices (Teshome, 2021). The emission from healthcare waste burning and incineration were not included due to lack of activity data on the volume of waste generated and incinerated.

2.17.4. Estimation of Emissions from wastewater treatment and discharge

The methane (CH_4) and nitrous oxide (N_2O) emissions from domestic wastewater was estimated using Tier 1 due to lack of activity data on the volume of domestic wastewater generation and types of treatment used in the country. The volume of wastewater was estimated using population data and income level. The fraction of population income group (Ui) value was taken from our nearest country Kenya as per the recommendation of IPCC guideline

Table 56 Treatment type, fraction of population and degree of utilization by income group

Income group	Type of treatment or discharge pathway	Fraction of population Income group [fraction] [Ui]	Degree of utilization [Tij]
	Septic system	0.8	0.02
	Latrine	0.8	0.38
	Other	0.8	0.04

Rural	None	0.8	0.56
	Septic system	0.04	0.32
	Latrine	0.04	0.31
Urban high	Sewer	0.04	0.37
	Other	0.04	0
	None	0.04	0
	Septic system	0.16	0.17
	Latrine	0.16	0.24
Urban low	Sewer	0.16	0.34
	Other	0.16	0.05
	None	0.16	0.2

The methane emission was computed using 0.6 default maximum methane producing potential and the methane correction factor (MCF) of 0.5 for septic system, 0.1 for latrine and sewer. Default values for methane correction factor (1.25 for collected and 1.00 for uncollected) were used for additional industrial BOD discharge in to the sewers. Similarly, nitrous oxide (N_2O) emission was determined by Tier 1 and annual per capita protein generation (kg/person/year) from FAO (2022) was used to calculate protein consumption as shown in. IPCC default values were used for fraction of nitrogen in protein, fraction of non-consumption protein and fraction of industrial and commercial co-discharged protein and nitrogen removed with sludge.

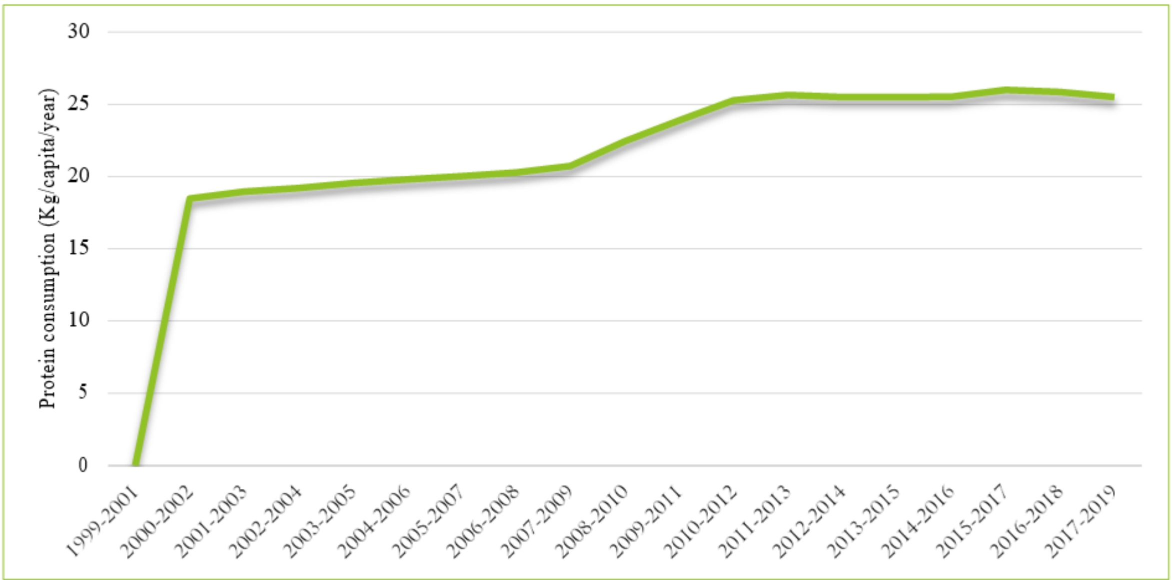


Figure 88 Trends of annual per capita protein consumption (kg/capita/year)

The wastewater discharged from sugar refining, beer and malt, dairy products, meat and poultry, plastics and resins, soap and detergents, wine and vinegar were estimated based on their total annual products. The methane emission was computed for wastewater treated in anaerobic shallow lagoon using 0.25 maximum for methane production capacity and 0.2 methane correction factor. It was also estimated for wastewater discharge to the river using the same value of methane production capacity and 0.1 for methane correction factor.

2.17.5. Quality Assurance and Quality Control (QA/QC)

Appropriate QA/QC system has been developed and implemented in line with the 2006 IPCC Guidelines for National GHG inventories. Quality controls applied for determining the National GHG Inventory from the waste sector include checking the integrity of activity data sources, correctness of parameters, units of activity data, conversion factors, and checking the emission factor and default value. Waste sector GHG emission estimation team determined that the results of the annual inventories, emission factors and assumptions applied as well as the methodologies used were reasonable and to the IPCC guideline standards.

2.17.6. Uncertainty Estimation and Reduction

The estimated GHG emissions and removals presented in the waste sector have uncertainty from several factors. These uncertainties include lack of activity data, lack of precession of activity data, methane correction factor and emission factor uncertainty due to incomplete knowledge of the processes that cause emissions and removals of GHGs. The 2006 IPCC guideline recognizes the uncertainty of estimates can’t be completely eliminated, i.e., estimates should be neither underestimated nor overestimated, while at the same time, whenever possible seeking to improve GHG emission estimates precession. The uncertainty of solid waste activity data is 120% and emission factor is 80% while the combined emission is 85%. The GHG emission from biological treatment has 5% uncertainty from activity data, 10 % for emission factor and 80% for combined uncertainty. In accordance with IPCC recommendation, uncertainty of activity data for domestic waste is ±30 and industrial wastewater is ±100. The uncertainty of methane emission factors and coefficients is estimated to be 80%. The combined activity data and emission factor uncertainty is estimated to be ± 70%.

2.17.7. Emission Sources

GHG emissions from the Waste sector result largely from disposal of solid wastes through landfilling, dumping, incineration, open burning and treatment of domestic and industrial liquid wastes. The emissions from solid waste are methane (CH_4) from disposal sites and predominantly CO_2 from open burning of waste. Wastewater can also be a source of CH_4 when treated or disposed of anaerobically as well as of nitrous oxide (N_2O) emissions. Domestic wastewater releases CH_4 when organic components in the wastewater anaerobically biodegrade while it releases N_2O as an intermediate product when nitrogen components in wastewater undergo nitrification (an aerobic process) and denitrification (an anaerobic process). Production of CH_4 associated with wastewater depends primarily on the quantity of degradable organic matter in the wastewater, the temperature, and the type of treatment system. Key factors that affect emissions generation are population growth, rural-urban drift and improper management of waste both at its source of generation and its final disposal.

Hence, improper waste management is a very critical issue affecting both human health and the environment through contamination and release of greenhouse gases. The GHG emissions from wastes can be mitigated by applying appropriate waste management. Therefore, this inventory aimed to estimate GHGs emission from solid waste disposal to land and from domestic and industrial wastewater handling; CO_2 and N_2O emissions from incineration and N_2O emissions from human sewage treatment.

The IPCC 2006 Guidelines divide the Waste sector into the following source categories: Solid Waste Disposal (4A), Biological Treatment of solid waste (4B), Incineration and Open Burning (4C) and Wastewater Treatment and Discharge (4D). Each source category is further divided into subcategories that take into account different waste attributes, management practices and approaches.

2.17.8. Activity Data Sources

Activity data for the waste sector categories covered in the inventory were obtained from the FDRE Environment Protection Authority (EPA), Ministry of Industry (MoI) and sectorial offices such as Sugar Corporation, Food, Beverage and manufacturing services, Central statistics Agency (CSA) and UNDP as shown in Table 62.

Table 57 Data type and their source for the different types of waste

Water Sector category	Data Type	Data Source
4.A –Solid waste disposal	Urban Population Data	UNDP (2018) World Urbanization Prospects; MoUDC (2020) report
4.C. Incineration and Open Burning waste		UNDP (2018) World Urbanization Prospects
4.C.2. Open Burning of Waste	Urban Population Data	Teshome (2021)
4.D Wastewater treatment and Discharge		
4.D.1. Domestic Wastewater treatment and discharge	Total Population data	UNDP (2018) World Urbanization Prospects, CSA
4.D.2. Industrial Wastewater treatment and discharge	Annual production	Ministry of Industry, Sugar Corporation, Food, Beverage and manufacturing services, EEPA.

2.17.9. Solid Waste Disposal

Anaerobic decomposition of MSW high in carbon content, emits mainly CH_4 while aerobic treatment and open burning or incineration yields mostly CO_2. In Ethiopia, there are very few engineered or sanitary landfills. Thus, municipal solid wastes either find their way into managed dump sites where compaction and sand filling of waste occurs or unmanaged ones where non-segregated waste is often heaped and occasionally the waste is burned to reduce the volume and health hazards. The latter constitutes most dump sites. Solid waste disposal activities are further categorized into: Managed Waste Disposal Sites (4.A.), Unmanaged Waste Disposal Sites (4.A.2) and Uncategorized Waste Disposal Sites (4.A.3).

2.17.10. Unmanaged Waste Disposal Sites

The available data on the quantity of municipal solid waste (MSW) generated in major cities in Ethiopia were used together with key socioeconomic data to estimate waste generation during the study period for the national inventory of solid waste. This data and characterization of MSW using the estimation protocol specified by the IPCC for the unmanaged waste disposal sites were used to estimate GHG emissions from MSW in Ethiopia.

2.17.11. Biological Treatment of Solid Waste

The emission of CH_4 and N_2O from biological treatment (composting) was estimated based on IPCC methodology(4.B)

2.17.12. Open Burning

Emissions of CO_2 and CH_4 emanate from open burning of municipal solid wastes which is presently practiced in Ethiopia due to the inability to collect all waste generated, especially in the rural areas, insufficient resources in the urban areas and the inexistence of managed engineered landfill sites. The emission estimation from solid waste covers only from urban and semi urban sources. GHG emissions from incineration of health care waste were also not included in the inventory due to lack of activity data.

2.17.13. Wastewater Treatment and Discharge

Wastewater treatment is divided into Domestic wastewater treatment and discharge (4.D1), and Industrial wastewater treatment and discharge (4.D2). Both approaches are practiced in Ethiopia. The methane (CH_4) and nitrous oxide (N_2O) emission from domestic wastewater was estimated using Tier 1 due to lack of activity data on the volume of domestic wastewater generation and types of treatment used in the country while estimation for industrial wastewater discharge was done on the basis of annual production. The GHG inventory addressed GHG emissions of CH_4, N_2O and CO_2 from the waste sector. The estimation was made for the years 1994-2018.

2.17.14. GHG Emissions from Waste Sector

2.17.15. Emission by Gas

In 2018, the greenhouse gas emissions from the waste sector were 22.85Gg of CO_2, 128.14Gg of CH_4 and 4.82Gg of N_2O compared with 3.10Gg, 41.2Gg and 1.79Gg, respectively for these three GHGs in 1994. Gas CO_2 recorded the highest increase of 637.1% when comparing emissions of 2018 over those of the year 1994. Methane emissions increased by 211.0% while N_2O increased by 169.2% over the same period.

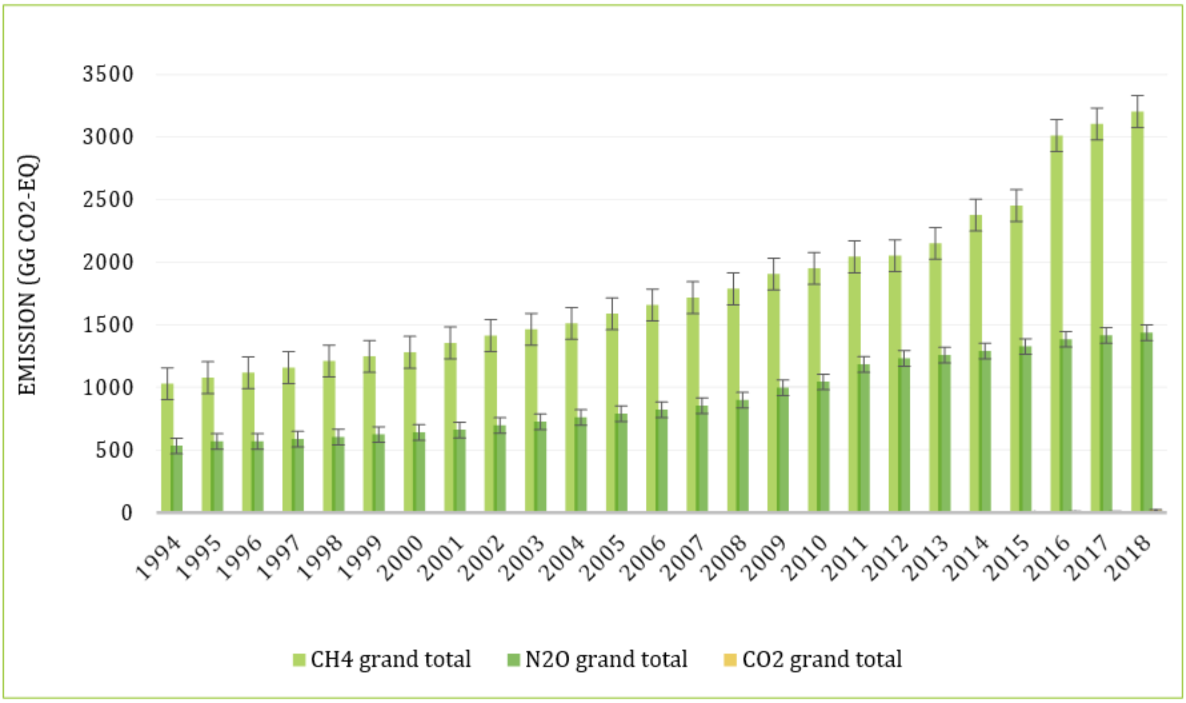


Figure 89 Aggregated GHG emission from 1994-2018

When taking into consideration the GWP of CH_4 and N_2O, the aggregated emissions of 2018 were 3203.42 Gg CO_2-eq and 1437.4 Gg CO_2-eq, respectively. In 2018, and on the same basis of equivalence, CH_4 topped the emissions with 68.7 % followed by N_2O with 30.8% and CO_2 with 0.5% of total aggregated emissions.

2.17.16. Emissions by Source Category

The annual emissions from the waste sector in the years 1994 to 2018 are presented in Figure 94. Total aggregated emissions for the waste sector was 4656.82 Gg CO_2-eq in 2018 compared with 1565.59 Gg CO_2-eq in 1994. This represents a 197.5% increase over the emissions of the year 1994 and 36.3% increase over the emissions of the year 2013.

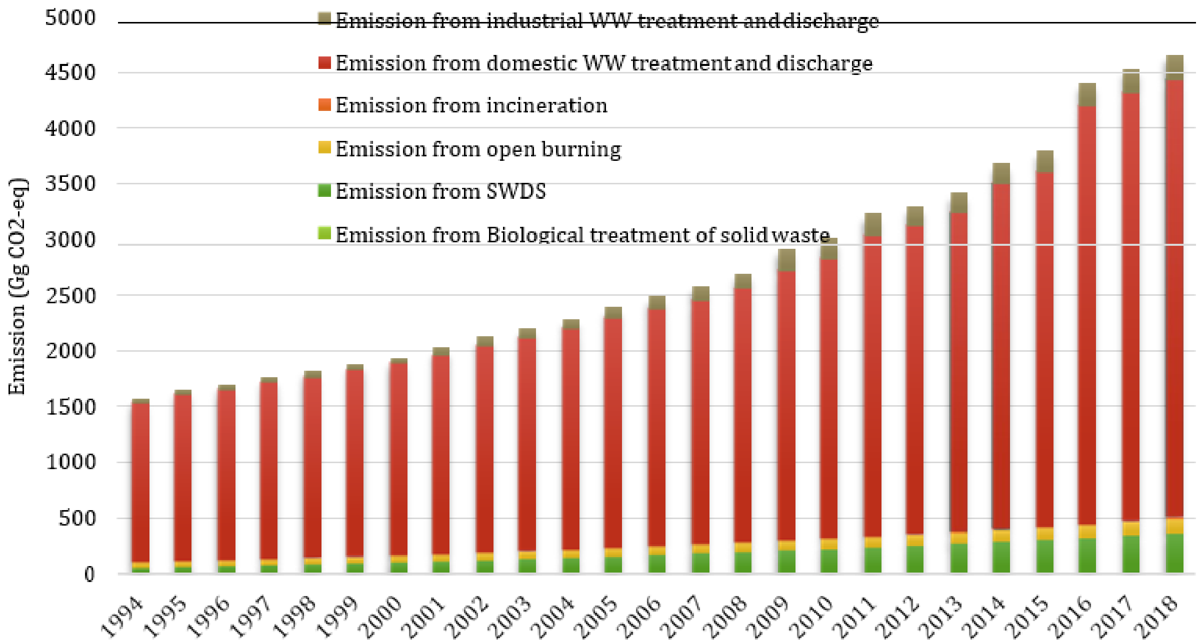


Figure 90 Emission from the different types of waste sector from 1994-2018 and percent contribution in 2018

Table 58 Aggregated emissions (Gg CO2-eq) of the waste sector

Sector/subsector	**Emission in Gg CO_2-eq**			**Level of Incrementin 2018 compared with**	
	1994	2013	2018	1994	2013
Solid waste disposal (4A)	59.81	273.62	361.52	504.5%	32.12%
Biological treatment(4B)	0	0	5.30	100%	100%
Incineration and Open Burning (4C)	40.67	94.91	130.88	231.2%	41.91%
Wastewater Treatment and Discharge (4D)	1465.11	3048.61	4155.31	183.6%	36.30%
Total Waste Sector	1565.59	3417.14	4656.82	197.5%	36.3%

In 2018, emissions from wastewater handling represented 87% (4155.34 Gg CO_2-eq) of total waste sector emissions followed by the SWDS category with 9 % (361.52Gg CO_2-eq) and the remaining 4 % (130.88 Gg CO_2-eq) came from open burning and incineration (Figure 2-49). From 1994 to 2018, the highest increase in emissions occurred under SWDS with 504.5 % followed by incineration and open burning (231.2%) and wastewater handling (183.6%).

Figure 2-49:

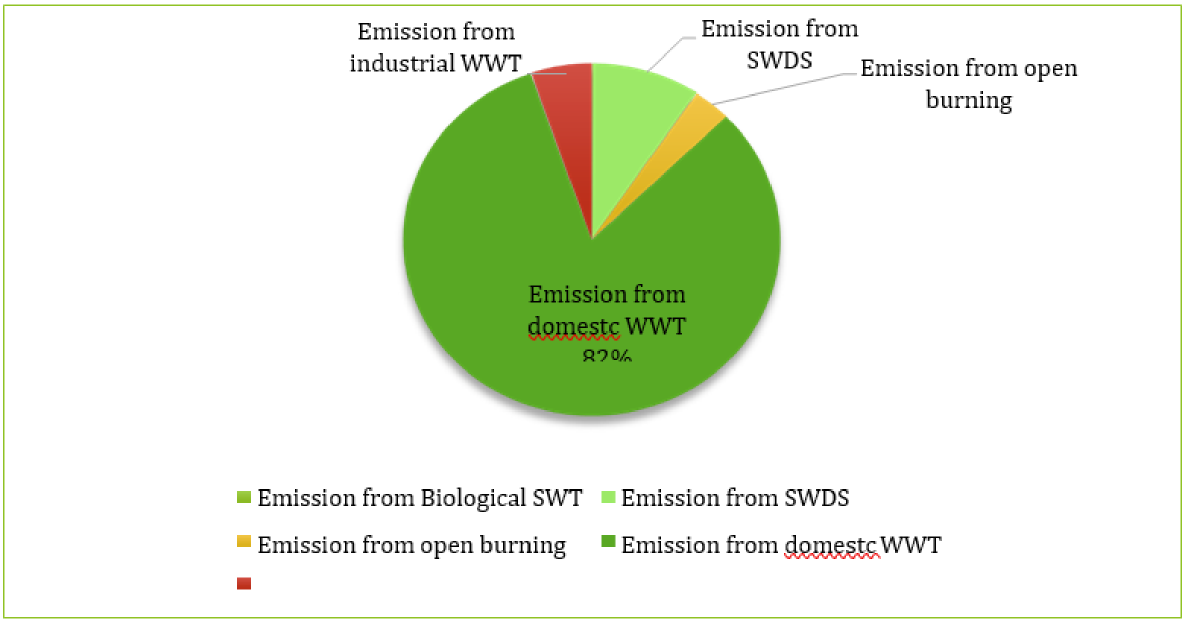


Figure 92 Contribution (%) by source category in emissions of the Waste sector in 2018

2.17.17. Emission from solid waste disposal sites

Emission from solid waste disposal sites (4A) showed linear increments from 1994-2018 and emission was 361.52 Gg CO_2-eq in 2018 compared to 1994 emission (59.81 Gg CO_2-eq) showing 504.45% and 32.12% increments compared with the year 2013 (Fig. 2.62). This is due to exponential growth of urban population as a result of pervasive rural-urban migration and unfolding urban development. In qualitative terms of mass composition, ''food waste'' and ''combined wood, and paper and cardboard waste'' were the major components responsible for CH_4 generation due to the disposal of municipal solid waste in landfills and dumps.

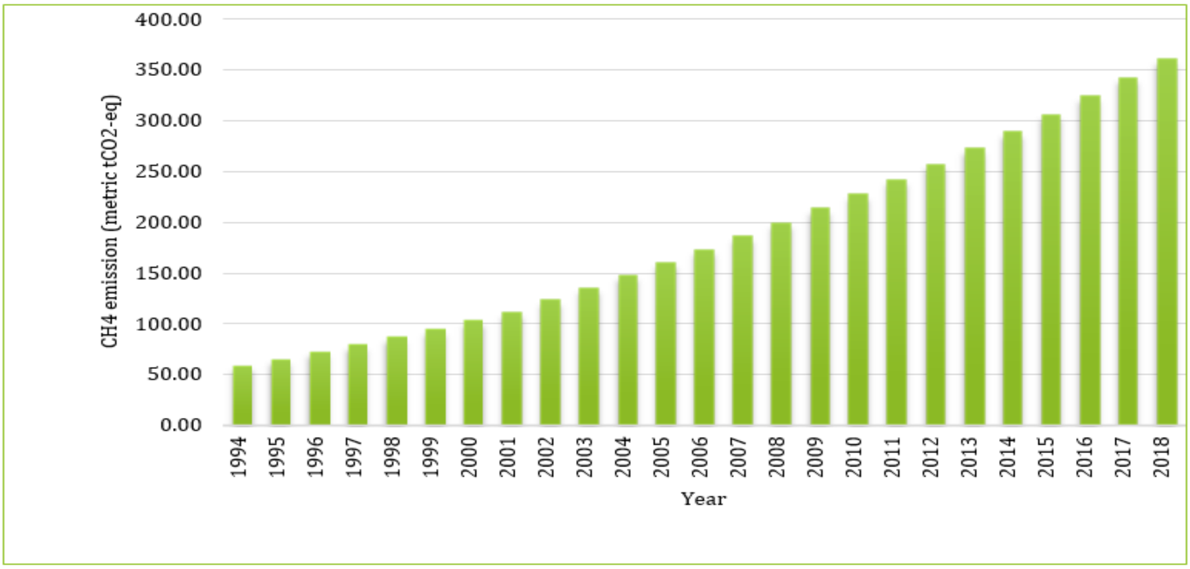


Figure 93 Emission from solid waste disposal from 1994-2018

2.17.18. Emission from Incineration and open burning

The emission from open burning and incineration was estimated to be 130.88 Gg CO_2-eq in 2018 (). Emissions from open burning and incineration of waste were increased by 221.18 % and 37.89% compared with emission in 1994 and 2013, respectively. This is attributed due to the widely customary practice of open burning of waste in Ethiopia, especially by the population that is not served by the selective garbage collection system. CH_4 contributed the highest GHG emission (73%) followed by N_2O emission (15%) and CO_2 contributed the least emission (12%). The emission from health care waste incineration was not considered due to lack of activity data.

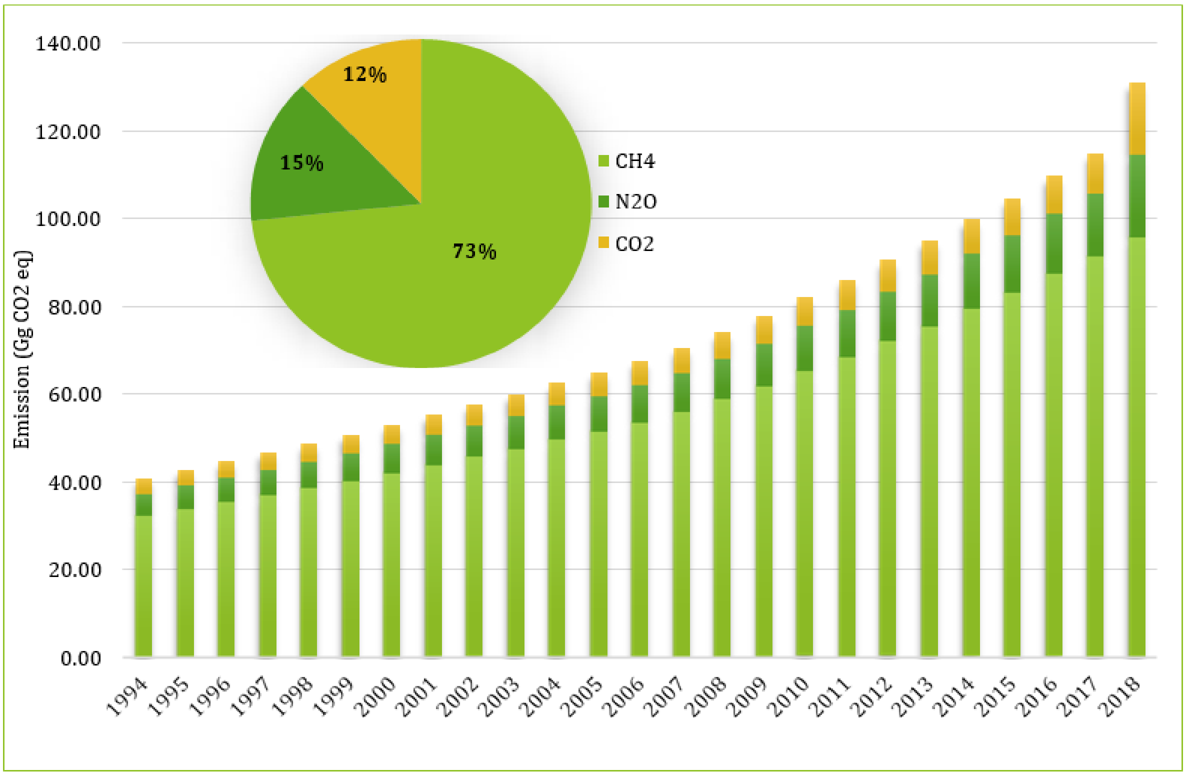


Figure 94 Emission from open burning of solid waste from 1994-2018 and emission proportion of CH4, N2O, and CO2 from the total GHG (Gg CO2-eq) in 2018

2.17.19. Emission from wastewater treatment and discharge

Emissions from wastewater treatment and discharge (4D) was estimated to be 4155.31Gg CO_2-eq in 2018 and this showed 183.62 and 36.3% increment compared with years 1994 and 2013, respectively (Figure 98). The domestic wastewater treatment and discharge (4.D.1) was the major contributor (95%) which was 3946.94 Gg CO_2-eq. This increasing trend is directly associated with urban population growth, expansion of the sewage collection and treatment system in the municipality. On the other hand, emission from industrial waste treatment and discharge was 208.4 Gg CO_2-eq with an increment of 803.3 and 24.82% compared with 1994 and 2013, respectively.

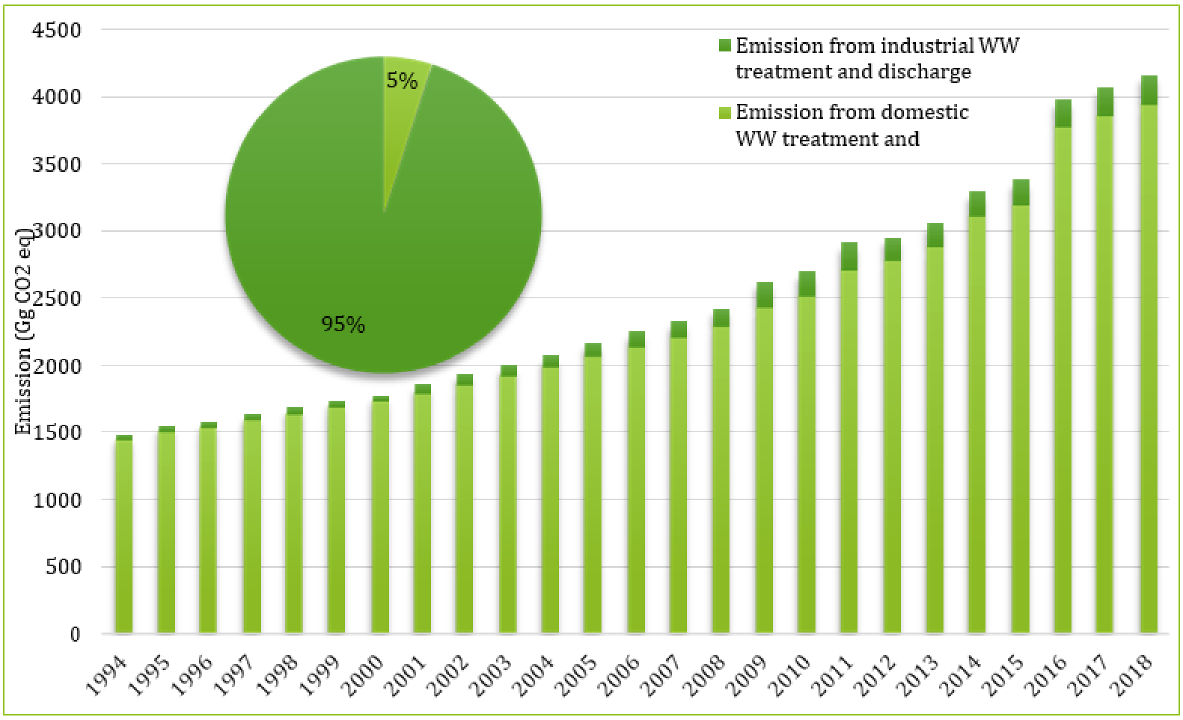


Figure 95 Emission from domestic and industrial wastewater treatment from 1994-2018

2.17.20. Recalculation

The total GHG emissions reported in the SNC from all sectors was 25,433.179 Gg for 1994 and 146,160.43 Gg for 2013. Whereas, the revised estimates for the SNC are 25,130.353 Gg for 1994 and 142,156.96Gg for 2013.

The recalculation results from 1994 to 2013 are estimated and indicated in the table below. Based on the recalculated results, the total GHG emission was increased from 1565.59 Gg in 1994 to 3417.137Gg in the year 2013 which increased by 465.7% while the increment was 474.68% in the SNC. The variation of GHG emission between SNC and the recalculated was due to the difference in activity data used in the estimation. For example, GDP data used in the SNC for estimation of industrial solid waste generation was one million times greater than the recalculation. There is also a difference in activity data used for solid waste generation, collection and climatic zone. There is also activity data input difference for estimating domestic wastewater generation. In the SNC 42% of the rural population is considered to have discharged their wastes into water bodies whereas this is not considered in the TNC because rural populations use either latrine or open defecation.

Table 59 Change of GHG emission (GgCO2-eq) between SNC and recalculations in 1994 and 2013

Year	SNC	Recalculated	Difference	Change (%)	Impact on national total (%)
1994	1,868.42	1565.59	-302.83	-16.2076	1.19
1995	2,046.30	1650.744	-395.55	-19.3301	0.32
1996	2,212.41	1690.161	-522.25	-23.6053	0.50
1997	2,388.44	1749.786	-638.66	-26.7395	0.49
1998	2,583.00	1818.59	-764.41	-29.5939	0.57
1999	2,764.62	1875.737	-888.88	-32.152	0.66
2000	3,054.59	1925.656	-1,128.93	-36.9586	0.62
2001	3,105.07	2019.955	-1,085.12	-34.9466	0.54
2002	3,091.97	2113.796	-978.17	-31.636	0.48
2003	3,403.98	2194.105	-1,209.87	-35.5429	0.59
2004	3,553.02	2276.815	-1,276.21	-35.919	0.81
2005	3,728.27	2384.314	-1,343.96	-36.0477	0.93
2006	4,189.25	2485.04	-1,704.21	-40.6806	1.14
2007	4,216.55	2577.839	-1,638.71	-38.8637	1.02
2008	4,900.66	2692.046	-2,208.61	-45.0676	1.25
2009	5,303.97	2910.116	-2,393.85	-45.1332	1.38
2010	5,678.66	3001.717	-2,676.94	-47.1404	1.44
2011	6,232.20	3233.841	-2,998.36	-48.1108	1.44
2012	6,664.93	3292.124	-3,372.81	-50.6053	2.37
2013	7,420.61	3417.137	-4,003.47	-53.9507	2.74

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3. CHAPTER THREE: NATIONAL GHG MITIGATION ASSESSMENT AND ANALYSIS

3.1. INTRODUCTION

Ethiopia is willing to reduce GHG emissions despite its negligible (0.04%) contribution to world GHG emissions. Ethiopia will achieve this by taking advantage of opportunities provided by low-carbon development pathways. In this sense, the energy, IPPU, AFOLU, and waste management sectors are recognized as being catalysts for the shift to low-carbon growth paths and a green economy. The nation takes mitigation into account in the context of sustainable development and aims to strike a balance between the need to address socio-economic and development challenges that it is currently facing and the nation's contribution to the global agenda laid out by the UNFCCC and Paris Agreement.

Article 4.2 (a) of the UNFCCC convention states that parties shall adopt national policies and take corresponding measures on mitigating climate change by limiting their anthropogenic GHG emissions and by protecting and enhancing GHG sinks and removal in order to reduce GHG concentration in the atmosphere (IPCC, 2014). In order to build climate resilience and reduce GHG emissions, rapid climate action at the global and regional levels must be made in light of the massive effects that climate change has already had on people, the environment, and the economy.

There are no mandated targets for Ethiopia to reduce GHG emissions under the UNFCCC because Ethiopia emits very little GHG. But Ethiopia committed to make a significant contribution to the Paris Agreement's aim of keeping the rise in global temperature to 2°C or less over pre-industrial levels. Over the past few decades, the nation has voluntarily implemented a number of policy measures that improve the implementation of climate change adaptation. To achieve economic development in conjunction with environmental preservation (green growth) such policy measures include the Climate-Resilient Green Economy (CRGE) plan (2011), National Adaptation Program (NAP, 2020), and National Determined Contributions (NDC, 2015 and 2021).

CRGE is continuing to be one of the strategic pillars and set a 10-year developmental plan during the NDC implementation period (2021 to 2030). The government was able to draw on policy and planning advancements including sectoral climate resilient strategies, the NAP (2017) and NAP implementation roadmap (2019) and it specified 40 adaptation interventions. Ethiopia is ensuring the legacy initiative to surpass its goal of planting 20 billion trees under the Green Legacy Initiative by the Prime Minister, which enhances carbon sink.

In the revised National Determined Contributions (NDC) for 2021 includes forecasts for climate change mitigation contributions under three different GHG reduction scenarios: the unconditional, conditional, and business-as-usual (BAU) pathway. In 2030, the absolute emission level under the unconditional approach will be 347.3 Mt CO_2 e. In comparison to the revised BAU emissions in 2030, which are 4.8% lower than the reduction promised in the previous NDC, BAU scenarios represent a reduction of 14% (-56 Mt CO_2 e), and the combined impacts of unconditional and conditional pathway contribution represent a reduction of 68.8% (-277.7 Mt CO_2 e). This ambitious course of action entails Ethiopia's unwavering efforts as well as international aid.

Additionally, sector-specific priority actions for mitigation and adaptation strategies were identified and prioritized in the amended NDC. As a result, it has already taken a number of steps to encourage mitigation based on local conditions. These include undertaking large-scale investments in the potential of hydro, solar, and wind energy as well as undertaking green legacy initiatives and afforestation projects. Ethiopia encourages adaptation and plans to investigate mitigation strategies that will encourage resource sustainability and help realize the objectives outlined in the Sustainable Development Goals (SDGs), AU Agenda 2063, NCCP 2017–2027, and other pertinent national policies and programs. However, strong assistance from the international community is essential for the nation to reach her full potential in terms of aiding in global GHG mitigation efforts.

The AFOLU sector is the largest contributor of GHG emissions, accounting for 90.86% of total emissions. According to the GHG inventory year, 2018, the agriculture sector, particularly livestock, has the greatest emissions (44%) and will continue to make the largest contribution in the years ahead, followed by the land use and forestry sector (30%). In the years 2018 to 2030, the two AFOLU sub-sectors account for 74% of total BAU emissions. The energy, Waste, and IPPU sectors each contribute 6.9, 1.46, and 1%, respectively. The pattern of GHG emissions in the country will be influenced by new realities such as the rapid expansion of the manufacturing sector and the growing urbanization of the population. As a result, emissions from solid waste, industry, and energy are expected to increase.

The mitigation goals of Ethiopia's NDC were outlined in relation to a BAU projection that took into account the reduction of emissions in four (4) socioeconomic sectors: waste, energy, and IPPU. Respective plans to reduce GHG emissions emphasize the following interventions: increasing access to modern and energy-efficient technologies in the transportation, industrial, and building sectors; protecting and re-establishing forests for their ecosystem services and ability to sequester CO_2; improving crop and livestock production practices for food security while reducing emissions. To reduce CH_4 emissions, waste management was addressed together with greater resource recovery (composting, waste to energy, and waste to energy from landfill sites). In accordance with updated NDC-2021 policies interventions of the Country, the third national communication mitigation and adaptation potential reports are represented based on key category level and trend analysis.

3.2. GHG emission projections

The GHG emission projection is presented according to different sectors. The AFOLU sector is the dominant source of emission throughout the 10 year (until 2030) followed by the Energy by the Energy sector. Emission projections for both the BAU, conditional and unconditional scenarios are based on key parameters which include, the national GDP, national GDP growth rate, national population (total, urban and rural) and population growth rate. These key parameters are drivers of the economy and national development plans, such as NDC, CRGE, provide for the projected changes in the future.

3.2.1.Energy Sector Emission Projections

The main human activity that emits CO_2 in the energy sector is the combustion of fossil fuels (coal, natural gas and oil) for energy and transportation. The energy sector has a 9.45% annual growth rate (Engdaw, 2020). The transport sub sector projected to 38012.08 Gg of CO_2 in 2030. From which, more than 50% of CO_2 is emitted by transport sub-sector in the same year. Manufacturing industries and construction and energy industries emit 30% and 14 % Gg of CO_2, respectively in 2018. Figure 100**Error! Reference source not found.** shows the projected emissions from the energy sector. Electricity is a significant source of energy in Ethiopia and is used to power homes, businesses and industry. The annual energy demand growth rate in Ethiopia is 25% and the energy consumption from the energy sector is projected as it can be seen from Figure 100.

The combustion of fossil fuels to generate electricity for transport is the first largest single source of CO_2 emissions in the energy sector as can be seen from Figure 100. Thus, the combustion of fossil fuels, such as gasoline and diesel, to transport people and goods is the largest source of CO_2 emissions. This category includes the use of fossil fuels for transportation services such as highway vehicles and aircraft. The country has adopted various measures to achieve the CRGE strategy, including use of electric powered vehicles and motorcycles, trams and the light rail transport system currently under construction.

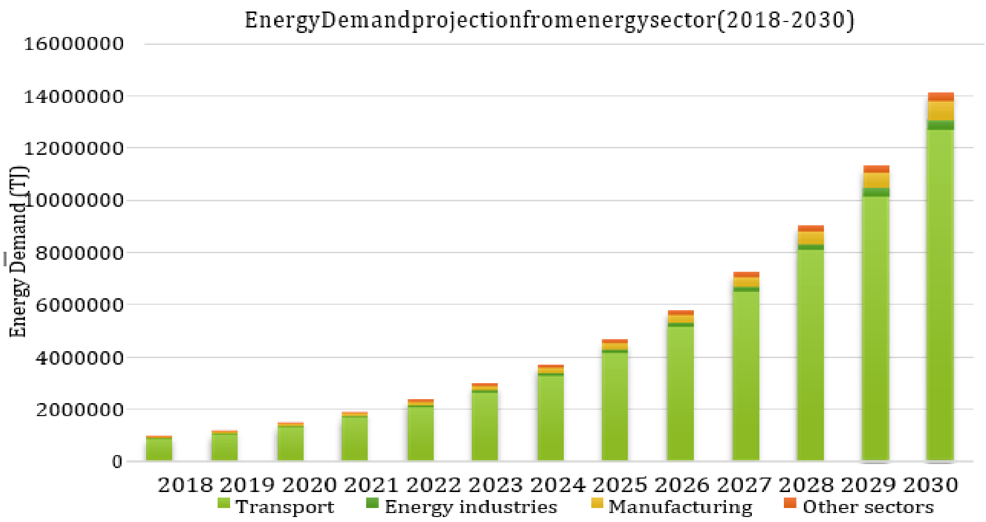

Figure 96 Energy Demand projection from energy sector (2018-2030)

3.2.1.IPPU Sector Emission Projections

Among the industrial sub-sectors, cement will be one of the fastest growing, also causing the vast majority of GHG emissions from the industry sector. Based on the 2018 estimated GHG emission from the IPPU sector in Ethiopia, cement and lime production have significant contributions to the national emission. It is also expected that these IPPU subcategories will continue to emit more CO2 in the future also.

Accelerated industrialization and expanded access to infrastructure through enhanced construction sector capacity are two of the primary country directions. The Ethiopian Cement Industry is anticipated to play a vital role in this respect, similar to many other nations, by supplying a wide range of cement products for the booming construction and infrastructure development. Because of this, the Government of Ethiopia considers cement to be one of the strategic industries that must be managed strategically in order to maintain the expansion of construction and infrastructure development in the nation.

According to FDRE Ministry of Industry Cement Industry Development Strategy 2015-2025, by the end of 2025 cement consumption of the country is projected to reach 19.97 million tonnes while the projected production required will be at 20.97 Mta. Based on the projected cement consumption and assuming a clinker fraction in cement of 95%, the CO2 emission cement is projected to be 10,359.18 Gg CO2 eq by 2025. This projected value is more than 3-fold, compared to the 2018 emission report and it is expected that the mineral industry, specifically the cement production source category, will emit a large amount of CO2. Further projection to 2030, the country's cement production is estimated to be 26.76 Mta (with 5% production growth rate). The emission also will be 13.219 Gg CO2 eq by 2030 from the cement sector. According to CRGE, In the industry sector, the highest potentials for reducing emissions have been identified in modernizing cement production to achieve higher efficiency. For instance, if a maximum of 70% of the clinker portion substituting with supplementary cementitious materials (SCM) including industrial byproducts can reduce the emission to 3.966 Gg CO2 by 2030. Other mineral industry sources such as lime are also expected to emit a significant amount of CO2 compared to other IPPU categories. Due to the lack of a national strategic plan on lime production, the projection of GHG emission from this sector is done based on average annual GHG emission for the period of 1994 to 2018. Accordingly, the projected emission from lime production is expected to be 913.74 Gg CO2 eq by 2025.

3.2.2.AFOLU Sector Emission Projections

The projections shows that with the BAU scenario AFOLU sector emission could hit 344,974.75 Gg CO2e by 2030 with the lower value 283,794.75 Gg CO2e and 406,154.76 Gg CO2e at 95% confidence interval.

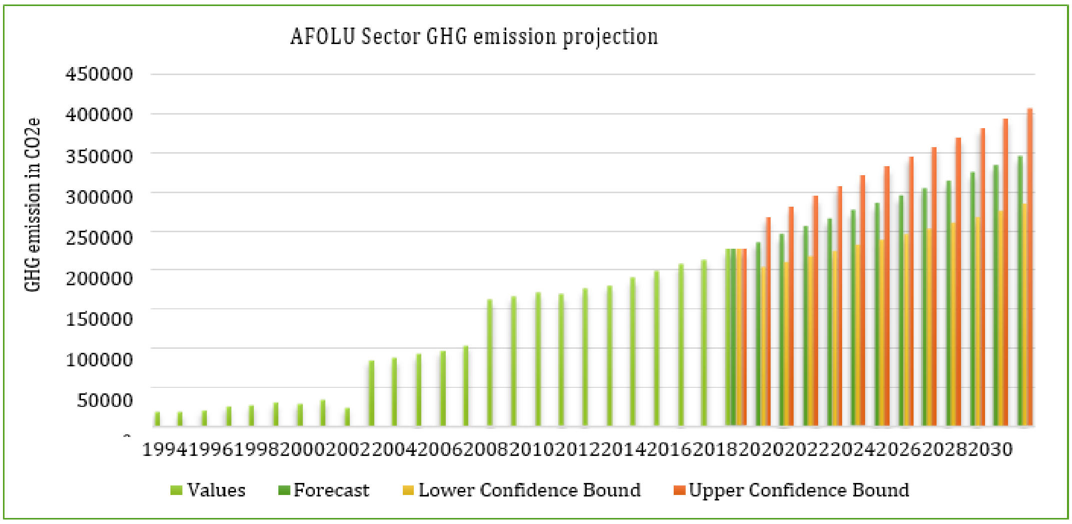

Figure 97 CO2 emission projection from liquid and solid fuels projections from 2018 to 2030

The total projected GHG emission was estimated to be 8511.9 Gg CO_2-eq (8.5M tone CO_2- eq) in 2030 for the increasing trend of waste generation in the business-as-usual scenarios. The highest emission was from domestic wastewater (5.2M ton) and industrial wastewater (2.4M ton) treatment and discharge. The emission from solid waste dumping was 596.4Gg CO_2-eq and this produced due to wastewater handling under anaerobic conditions and anaerobic decomposition of organic waste disposed of in solid waste disposal sites (SWDSs).

3.3. Energy sector analysis, assessment, and mitigation options

Ethiopia's current contribution to the global increase in GHG emissions has been practically negligible. This is because energy generation in the country is mainly from renewable sources and hydropower has the lion's share of the grid-connected electric system of the nations.

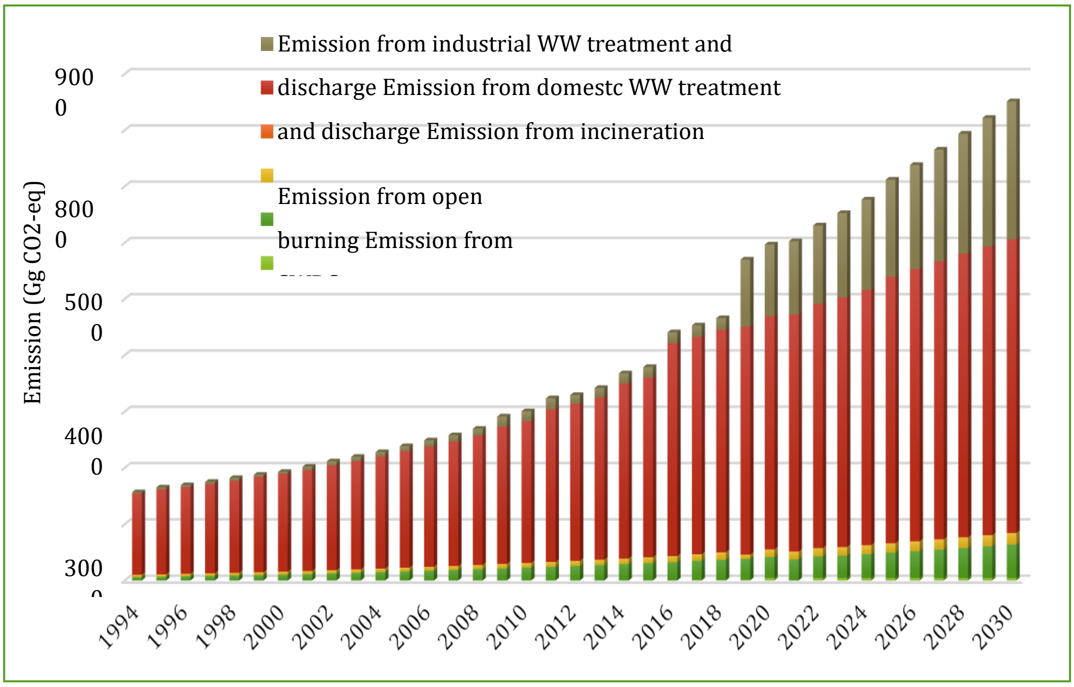

Figure 98 Shows the trend and projections for emissions from the waste sector

Moreover, the contribution of emissions from biomass energy sources has been already accounted for in the LUCF sector. Even after years of rapid economic expansion and growth, today's per capita emissions are less than 0.2t CO_2e. According to the recently updated NDC, the energy sector, along with livestock and LUCF, has significant mitigation potential. Renewable energy accounts for the vast majority of grid-connected electricity generation. In 2030, the energy sector will account for only 5% of total BAU emissions. Policy interventions in this sector will also reduce emissions to 9.5 Mt CO_2e in 2030 under the conditional pathway. This equates to a 52.5 percent reduction in emissions (-10.5 Mt CO_2e) when compared to BAU emissions in the energy sector. Energy policy interventions target energy consumed by all sectors. Investments in the transportation sector can help to reduce demand for petroleum by accelerating the transition to green mobility solutions such as e- mobility, railways, and non-motorized transportation.

Table 60 Policy interventions in the energy sector

Policy intervention	Indicator (unit)	Lead institution/s (responsible)
Energy efficiency . Economy-wide improvements in energy efficiency of appliances, machinery, and other capital assets	Efficiency parameters, e.g., efficiency of appliances and buildings (in %)	Ministry of Water, Irrigation and Electricity (MoWIE)
Transport electrification . Shifting transport energy demand from petroleum to electricity . Increasing the share of electric vehicles	Energy demand shifted (TJ) Share of electric vehicles over total fleet (%)	Ministry of Transport (MoT)
Public transport . Shifting transport energy demand from petroleum to electricity . Increasing the share of public transport, including railways	Energy demand shifted (TJ) Passenger distance traveled in public transport (km) (By women/ men) Share of passenger kilometers traveled in public transport over total passenger kilometers traveled (%)	Ministry of Transport (MoT)
Industry fuel switches . Fuel switch 1: shift from industrial petroleum demand to electricity . Fuel switch 2: shift from industrial petroleum demand to sustainable biomass	Energy demand shifted (TJ) by type of fuel switch	Ministry of Trade and Industry; Ministry of Water, Irrigation and Electricity (MoWIE)

Source: Updated NDC 2021

3.3.1.Possible Mitigation Strategies for The Energy Sector

Ethiopia has followed Agriculture Development Led to Industrialization (ADLI) as a leading and overall national economic framework strategy to fight poverty and attain industrialization in the long run for more than two decades. Hence, the national economy will undergo structural change in the coming years. As it has been signified in the 10-year Development Plan, the manufacturing sector is supposed to be the base of the national economy in the future. Related to manufacturing, the pace of urbanization could also be high in different parts of the country. These emerging realities will have their cumulative consequences on the patterns of emissions. Thus, emissions from industry, mainly from manufacturing, are expected to increase by a larger percentage compared to previous years. Mitigation activities in the manufacturing sector are the part and parcel of mitigation action in the industrial sector. Cognizant of this, commensurate interventions have been proposed to reduce emissions coming from the industrial sector in the coming years. As part of the energy sector, manufacturing has huge mitigation potential in the updated Nationally Determined Contribution NDC.

Some of them are the following:

- Awareness creation activities on climate change and the relevance of climate change mitigation should be given to managers of the industrial sector.
- Shifting the energy system to grid-connected electricity generation that comes from renewable sources is the dominant one.
- Adopting renewable energy sources like solar, wind, and small hydro help the manufacturing sector be more sustainable than non-renewable-based ones.
- Improving processes reduces the energy required to operate the manufacturing equipment, so there are fewer CO_2 emissions and less dependence on non-renewable energy.
- Incentivize a transition to low-carbon energy sources to unlock greater emission potential alongside reduced air pollution.
- Improving resource and energy efficiency in manufacturing processes.
- Setting high emission reduction targets is a nice way toward a net-zero greenhouse gas economy.
- Creating a synergized energy system that reduces the reliance on fossil fuels, recycling components, and adopting more environmental design practices will be critical approaches and will insist on a better way of mitigation action.

3.4. IPPU sector analysis, assessment and mitigation options

The IPPU sector was considered to be less significant compared to Energy and AFOLU. Most of the industries in Ethiopia are small and micro such that they don’t emit much GHG. As the mineral industry (cement industries) takes the lion’s share of the GHG emission for the target years, the primary mitigation options focus on emissions from cement production. Furthermore, in line with this report, the nationally determined contribution (NDC) has identified the cement sub sector as the major source of process- related emissions in the industrial sector. Cognizant to this, the principal policy to mitigate process-related emissions in the cement sector is clinker substitution. The policy intervention in the industry sector indicated clinker substitution as replacement of the clinker in cement with adequate and available materials without compromising cement properties. Accordingly, in order to reduce the CO_2 emission from the cement industry the following measures can be recommended as mitigation options:

1. Improved energy efficiency of the process by converting the technology used from dry to precalciner kilns and from rotary to grate coolers and by introducing computerized energy management and control systems, which can decrease the energy demand and hence the cost of emissions from cement production
2. Addition of specific decarbonated or limestone-free components to the raw materials mix, beforekilning,
3. Substituting a portion (up to 30 to 40 %) of the clinker with supplementary cementitious materials (SCM) without compromising cement strength. SCM include industrial byproducts such as fly ash, bottom ash from waste-to-energy plants, ground granulated blast furnace slag (GGBFS), natural (volcanic) pozzolans, calcinated clay (metakaolin), bagasse ash, etc.
4. Using limestone calcined-clay cements (LC3). These can replace up to 50% clinker and reduce GHG emissions by 30%. The components of LC3 are clinker, calcined clay, limestone, andgypsum.

Ethiopia also seeks support on capacity building and technology transfer including clean cement production in order to reduce emission from this sector.

3.5. AFOLU sector analysis assessment, and mitigation options

The Climate Resilient Economic Growth Strategy (CRGE) has earmarked 60 mitigation options for low-carbon growth and climate resilient growth in agricultural crop, livestock and forestry sectors. Out of the four pillars earmarked in the CRGE improving crop and livestock production practices is the major one. Similarly, the updated NDC has identified 40 adaptation interventions; the bulk of these are mitigating emissions from the AFOLU sector.

3.5.1.Livestock

The contribution of GHG from livestock is expected to grow due to increasing populations of livestock triggered by increasing demand for animal protein. This calls for applying mitigation options such as reducing the cattle population as the share of cattle to the overall emission of GHG from the AFOLU sector is higher. The largest livestock population in the country has made the sector carbon-intensive which invites population reduction as a mitigation option. As the population reduction alone could have a negative impact on milk and meat production an integrated mitigation approach such as reducing the livestock population and replacing local variety with the improved one should be taken to maintain/improve milk production. Since the emission of chicken and small ruminant meat is much lower than cattle meat, mitigation options towards substitution of cattle meat with chicken and small ruminant meat could have a promising abatement potential. Methane is produced by the decomposition of manure under anaerobic conditions. When stored in liquid or slurry form, anaerobic decomposition is greater and more methane is released, and when stored as solid less methane is released. Therefore, the manure management system should be improved.

Improvement in the livestock production practices alone is expected to have an abatement potential of 48Mt CO_2 eq. which is 1/5th of the abatement potential of the country as per CRGE strategic document. The livestock production system in Ethiopia mainly depends on poor quality feeds which leads to methane emission from the enteric fermentation and the manure management. Therefore, the following mitigation options needs to be considered in order to reduce emissions from the sector:

- Rangeland and pastoral land management
- Improving livestock production system (feed/forage diversification; improved animal breeds)
- Enhancing and intensification of animal mix (dairy, poultry, small ruminants, improved breeds)
- Drought-resistant animal breeding
- Animal health care and reproductive improvement
- Manure management
- Livestock value-chain efficiency improvement (processing, marketing,)

3.5.2.Land/Forestry

Expansion of small-scale and large-scale agricultural activities were identified as major drivers of deforestation and forest degradation. The natural growth of population in the forest areas coupled with the continued spontaneous in-migration into those areas has resulted in an increased rate of deforestation due to expansion of small-scale agriculture. Large-scale agricultural investment (such as coffee and tea plantations, irrigated farming, cotton, sugarcane and oil crop production, etc.) sometimes include conversion of extensive natural high forests and woodlands into non-forest land.

The dependence on biomass energy is high across all regions and this has a huge pressure on the native forests. Unsustainable extraction of wood for fuel (charcoal making, branches, leaves and twigs for firewood) is the main cause of forest degradation in the country. An increasing livestock population combined with free grazing that leads to overgrazing in forest areas is the main driver of forest degradation (especially degradation of the woodland vegetation and reduced regeneration in forest ecosystems). Forest conversion to grassland holds a significant share of greenhouse gas emissions in Ethiopia. Illegal and excessive wood extraction in the remaining high forests and dry forest areas or woodlands for industrial and construction purposes distributed across the forest regions is also another driver of forest degradation.

- Improve management of natural forests and woodlands through institutional and human capacity building and implementing forest management schemes
- Increase afforestation, reforestation, and sustainable forest management to increase carbon sequestration in forests and woodlands
- Strengthen community-based forestry
- Sustainable forest management and conservation

- Reduce demand for fuel wood via the dissemination and usage of fuel-efficient stoves and/or alternative energy technologies for lighting, cooking and baking (such as electric, solar, or biogas stoves) leading to reduced forest degradation
- Low-emission climate smart agriculture and improving agricultural production techniques
- Improved livestock production, value chain and management
- Strengthen law enforcement activities to combat deforestation and forest degradation through increased capacities of the forestry institutions
- Clean Development Mechanisms (CDM) in Ethiopia started in 2012. But its progress is very slow. Until now, only one project is certified and generating carbon credits. Organizing community-based afforestation/reforestation and other clean development projects and recruiting in CDM is important for a sustainable mitigation approach.

The CRGE strategy has put a plan to afforest 2 million ha of land and reforest an additional 1 million ha of land. Further, Ethiopia pledged for the Bonn Challenge to restore additional 15 million ha of degraded lands. Implementing such an ambitious plan would offset the carbon emission and enhance the forest carbon stock.

3.5.3.Agricultural Crops

The N_2O emission from agricultural soils is mainly due to the application of inorganic fertilizers and/or manure when the crops cannot uptake all of the applied nitrogen (N) due to the growth stage not requiring all of it or when soil N concentration is high. The mitigation options, therefore, include the use of fertilizers based on soil maps and specific crop requirements. Giving a plant the right nutrient at the right time will not only increase yield but also reduces the N_2O emission. In addition, replacing synthetic/highly volatile N fertilizers with high-quality compost will reduce the N_2O emission.

- Soil carbon storage and management
- Nitrogen Management
- Tillage and residuemanagement
- Agroforestry
- Smart agricultural practices
- Water management techniques
- Climate-smart agriculture;
- Improved drought-resistant crop varieties;
- Watershed management andrehabilitation;
- Ecosystem-based adaptation

3.6. Waste sector analysis, assessment and mitigation options

In the waste sector, management options for solid waste and wastewater are considered because it is one of the contributors to the GHG emissions. The rising trend in GHG emissions is closely linked to population growth, urbanization and changes in lifestyle. With a projected urban population of nearly37.5million in 2030 and per capita waste generation of 113.15 kg/capita/year, total solid waste is expected to rise by 4243.125 thousand tons every year. The management of such volumes of waste has major technical, logistical and financial challenges especially to city authorities. Similarly, GHG emissions are likely to be more than triple compared to the 1994 – 2018, an average of 8511.9 Gg CO_2 eq (8.51MT CO_2 eq) by 2030. Despite this, there are opportunities for avoiding such levels of emissions in the baseline scenario. The challenge is how to convert solid waste threats to opportunity in using as a renewable resource and financial gains via recycling and resource recovery as well as manufacturing durable products. UNDP (2016) also reported that the average annual percentage of composted waste from the six major cities of Ethiopia (Bahir Dar, Bishoftu, Hawassa, Dire Dawa, Mekelle and Adama) was: 0.42% (2016), 2.25% (2017), 5.60% (2018), 10.22% (2019), 14.48% (2020) and 18.51%

(2021). The resource recovery potential through composting in Ethiopia showed an increased trend. Despite small contributions of the waste sector to total GHG emissions, policy interventions in the waste sector can be highly effective to reduce emissions. Mitigation action in the waste sector has a significant potential to reduce GHG emissions. The updated NDC (2021) stipulated that conditional interventions to the waste sector can reduce the emission level to 2.21 Mt CO_2e in 2030 from BAU emission projections (8.51 Mt CO_2e). This equals a relative emissions reduction of 74.7% (-5.3 Mt CO_2e) compared to BAU emissions in the waste sector. There are many policies, proclamations, strategies, legal and institutional framework to achieve the GHG emission reduction in the waste sector. Some of the existing documents to enable and support the sector are listed in (

).

Table 61 Sectoral policies, legal and institutional framework

No.	Policies	Description
1	Constitution of Ethiopia, 1995	Sets environmental rights and objectives. Article 44 stipulates that; “All persons have the right to a clean and healthy environment”. Similarly, article 92 states the responsibility of the Government in striving to ensure a clean and healthy environment for all Ethiopians, in maintaining the ecological balance while conducting any economic development activity.

2	Environmental policy of Ethiopia,2007	Overall goal was to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment to meet the needs of the present and futuregenerations.
3	Urban development policy, 2014	EnsuringEnvironmentalConservationandSanitationinCities, the government and people should focus on making sure that cities do not suffer from overcrowding and pollution as they grow and the enforcement of national and regional policies regarding environmental conservation, waste disposal.
4	Urban Wastewater Management Plan, 2015	Planned to implement water supply and sanitation systems including domestic wastewatertreatmentin36majorcitiesof the country.
5	Solid Waste Management Proclamation (513/2007)	It aims to promote community participation in order to prevent adverse effects and enhance benefits resulting from solid waste. It provides for preparation of solid waste management action plans by urban local governments.
6	Solid waste management Strategy	The strategy was prepared based on ISWM approach, reduction, Reuse, recycling strategies and compost of organic solid waste, energy recovery from waste incineration and final disposal. It also emphasizes the roles and responsibilities of stakeholders to implement strategies.
7	Environmental Pollution Control Proclamation (300/2002)	Primarily focus is based on the principle that each citizen has the right to have a healthy environment, as well as the obligation to protect the environment of the country.
8	Prevention of Industrial Pollution Regulation (159/2008,)	Regulation confers important obligations to industrial operators. A factory subject to the regulations is obliged to prevent or minimize the generation and release of pollutants to a level not exceeding the environmental standards
9	CRGE Strategy	EthiopianCRGEStrategymainfocusistogrowfast,sustainable and become green.

3.6.1.Mitigation Options

Integrated Waste Management

Improving solid waste management is crucial for countering public health impacts of uncollected waste and GHG emissions of open dumping and burning. Integrated solid waste management (ISWM) plans are an effective means of implementing important waste reduction strategies, and hence to reduce GHG emissions. It addresses waste reduction at source; recycling and resource recovery practices as well as waste-to-energy options.

Source reduction

Source reduction is the first tier of the solid waste management hierarchy. Source reduction is used to describe those activities that avoid or decrease the amount (weight or volume) of waste generated. Source reduction encompasses those activities that increase product durability, reusability and reparability or avoiding generation of waste. These in turn reduce GHG emissions from the waste sector.

Recycle, Recover andReuse

Recycling: urban solid waste recycling activities in Ethiopia are at an infant stage and conducted via informal and unregulated collection systems. Recycling utilizes the social sector known as scavengers ("Korallio") - citizens with low- to no-income groups collect materials that are dispersed throughout the cities and/or concentrated at dump sites and supplied to formal waste recycling companies. The common item used for recycling includes paper, plastic, metal, and glass. According to Addis Ababa solid waste management agency (AASWMA) 59,859 tons of solid waste were collected and recycled annually. These practices have to be enhanced and supported by institutions.

Composting: 60-70 % of solid waste is organic carbon in nature. The application of compost as organic fertilizer from waste promotes, over time, a buildup of carbon which could prove to be a ''sink" for the carbon sequestered in the soil. Soils play a major role in the global carbon cycle and the application of compost can therefore mitigate climate change effects by retarding CO_2 release into the atmosphere. The carbon saving from energy used in the production of fertilizer should also be included. In response to the country's GHG emission reduction plan (NDC, 2021), composting activities will be practiced in Addis Ababa and Major regional cities. In 2017 and 2018 from six major cities a total of 5,126 and 8,015 tons of organic wastes were composted and was increased to 29,652 tons in 2020. In Addis Ababa city during the year of 2012 and 2013; 1,015 and 842 tons of organic waste was composted. Therefore, composting and organic fertilizer production from waste should be strengthened, institutionalized and sustainable for value addition and GHG mitigation from organic waste.

Waste to Energy: the use of landfilling as a disposal method of MSW in Addis Ababa becomes a crucial issue due to depleting available cheap land resources and the wasteful nature of disposing useful resources in the landfill operation. Therefore, Addis Ababa Municipality established and operated a new Reppie - waste-to-energy plant with the designed capacity of 50MW. The plant is said to be Africa's first waste to energy facility, which was inaugurated in 2018. The plant is generating about 25MW of electricity per day and currently, it incinerates solid waste of 1000 tons every day, which is roughly 80% of the city's garbage. This mode of CO_2 reduction is counted under energy production emissions. However, the plant is not fully operational owing to a lack of raw materials and financial resources.

Figure 99 Reppie Waste-to-Energy facility

Sanitary Landfill: Sanitary landfill is an essential tool for mitigation of GHG emissions and disposing safely of all types of solid waste. This is the only option of the unwanted product of other solid waste treatment options. Even though the investment cost of incineration is not attractive, its impact on methane emission from solid waste is significant. In Ethiopia, e 2008 class 2 and class 3 level Sanitary landfill sites were constructed in six cities (Jimma, Bishoftu, Semera, Debremarkos, Harar and Adigrat) which need to be strengthened.

3.6.2. Options For Mitigating GHG From Wastewater

The industrial sector grew about 7.3% in 2021 and will grow faster in the coming decades. However, wastewater treatment is still a challenge due to its wastewater installation and maintenance cost. This leads to discharging partially treated wastewater to the environment. The habit of open field disposal of liquid waste is one of the main causes of soil and water contamination and GHG emissions. The management of liquid waste at household level is very poor. The Ministry of water, Irrigation and energy has developed an Urban Wastewater Management Plan in 2015 and tried to indicate the concern of the issues in its policy. Although sewerage was planned to be implemented in 36 towns in the water supply and sanitation plan document, the progress is still low. Addis Ababa is the only chartered city that started the implementation of sewerage system expansion and new construction.

Even though there is higher population and infrastructure growth, the wastewater management system lags behind which needs serious attention in the coming future. High cost of implementation and weak institutions arrangements are the main challenges of authorities lacking the capacity to manage and maintain such facilities. Strengthening the proclamations, policies and strategies should be supported by standards and guidelines which help to implement and monitor the ongoing operation as efficiently as required and to mitigate GHG emissions. Those developed standards need to be enforced by laws and regulation, structural standards and penalties when understood between all stakeholders. Strong institutional arrangement, political commitment, financial stability, reliable and affordable technology, effective business models and skilled manpower will lead the wastewater management system to the target set by national strategies. As a result, the environmentalimpactsofwastewaterwillbereduced.

Figure 100 Akaki Kality UASB Wastewater treatment plant, Addis Ababa

In order to reduce GHG emissions from wastewater, aerobic wastewater treatment systems and aerated or shallow (<2meter) lagoons are also recommended, to reduce CH_4 gas emission. Methane recovery from anaerobic wastewater treatment such as up flow anaerobic sludge blanket (UASB) with methane recovery of the flaring system is also recommended. Connecting the domestic wastewater to the sewer line will also reduce methane emission.

Table 62 Waste sector GHG mitigation options

Category	Mitigation option	Description
Improve waste collection services, source separation and	Source reduction	reduce the amount of waste generated by strategic planning such as; Education to create norms, reduce over packaging or using disposable packaging, selective purchasing and conduct waste stream audit.

Solid waste management practices	Reuse /Recycling	Wastes such as furniture products, cloth, Glass, plastics can be reused. paper, plastic, metal, and glass can be
		Recycled. Such schemes should be institutionalized and scaled for sustainability.
	Composting/Bio-fertilizer	60-70%ofsolidwastegeneratedisorganic which can be Composted as:
		manure compost -from hours, cow and chicken manure
		Worm castings (Vermicomposting) from garden and kitchen waste Green waste compost- for municipal waste Composting/Bio- fertilizercanbea"sink"for the carbon sequestered in the soil and reduce urea application. This in turn reduces GHG emissions.
	Waste to Energy	Incineration - Waste to Energy/electricity conversation
		Biogas production
		Production of briquettes and charcoal for fuel and bricks production from waste
	Sanitary Landfill	Sanitary landfill with CH_4 capturing is an essential tool for mitigation of GHG emissionsanddisposingsafelyofalltypes of solid waste. It also reduces health impacts
	Avoidance / ban - production	Avoiding using non degradable plastic materials; such as plastic water bottles, plastic bags etc.
	Improved fecal sludge management (Rural and Urban)	Depending on the contamination profile, reuse it as a soil amender. Building centralized treatment facilities (aerobic and anaerobic).
Improve Urban domestic and industrial Wastewater management	Advanced/ integrated wastewatertreatment System	Aerobic wastewater treatment used to reduce CH_4 emissions
		Anaerobic wastewater treatment such as up flow anaerobic sludge blanket (UASB) withmethanerecoveryforenergy utilization or flaring system is recommended.
	Sewer line connection improvement	Connecting the domestic wastewater to the sewer system with advanced wastewater treatment will reduce GHG emissions.

	Zero Liquid discharge	Treat and reuse the wastewater
	Aerated Lagoons	Aerated Lagoons reduce methane emission from wastewater.

3.6.3.Key Barriers to GHG Mitigation in The Waste Sector

i) Policy and regulatory barriers: - unclear legal and regulatory frameworks, weak policy implementation and limited law enforcement

ii) Institutional barriers: - several institutions are involved in waste management such as recycling and composting, where there might be potential conflict roles and or functions.

iii) Technological barriers: - these include availability of technologies, high cost and inadequate technical expertise.

iv) Socio-economic barriers: - the negative perception of the society in handling, and using it for value added products such as compost and recyclable materials.

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4. CHAPTER FOUR: VULNERABILITY IMPACTS, AND ADAPTATION ASSESSMENT

Climate change is a real and global developmental challenge that requires immediate and long-term plan and intervention. Ethiopia is among the most vulnerable nations to climate change and extremes mainly due to its location (see Fig. 1), the nature of economy and livelihood base as well as low adaptive capacity. In Ethiopia, climate change and extremes such as recurrent drought, flood, ever rinsing temperature, erratic rainfall distribution behavior compromise the government and stakeholders' sustainable development efforts. For instance, climate change and extremes have been causing land degradation, shortage of pasture, water scarcity and pollution. Climate change is also responsible for the prevalence of disease, conflict, migration, and for the decline in agricultural production thereby hampering the growth of the national economy and wellbeing of the rural community. The cumulative effects of climate change are bound to worsen poverty and food insecurity which in turn would erode adaptive capacity.

Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed to its sensitivity, and its adaptive capacity. Adaptation is referring to adjustments made to natural or human systems in response to actual or expected climatic extremes with the intent of mitigating harms (IPCC, 2007). Thus, understanding the climate change impacts, nature, and magnitude of the vulnerability of sectors and segments of the community is the cornerstone for a sound response. Ethiopian agriculture, water, health, wetland, forestry, tourism, biodiversity, infrastructure are climate sensitive sectors. Therefore, sector specific climate change and extremes impact assessment, vulnerability and feasibility adaptation strategy is utmost important to properly respond to the adverse impact of climate change and extremes. More specifically, the analysis of changes in precipitation frequency and intensity, changes in average annual run-off, changes in water quality, changes in water demand and groundwater changes, magnitude and frequency of drought and flood, heat related stresses etc could provide clear understanding to reduce vulnerability and properly respond to the impacts and causes of climate change.

4.1. Climate change vulnerability, impacts and adaptation assessment methodology

Various complementary approaches were used to understand the climate situation, sectors vulnerability and adaptation responses. The assessment of climate change vulnerability and adaptation section was prepared based on the IPCC technical guidelines (1996), refined IPCC guidelines (2019) and NAPAs guidelines (2002). Hence, a mix of approaches and methodologies were employed. Accordingly, in Ethiopia the frequency and magnitude of climate extreme events in the climate sensitive sectors are remarkable. Cognizant of these precipitation and temperature extreme events were examined using gridded precipitation (SBP) (Derin et al., 2018) and Climatic Research Unit (CRU) data respectively. Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 35+ year quasi-global rainfall data set. It is a new quasi-global (50°S-50°N) (and all longitudes), high resolution (0.05°), daily, pentanal, and monthly precipitation dataset ranging from 1981 to near-present. CHIRPS incorporates our in-house climatology, CHPclim, 0.05° resolution satellite imagery, and in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. CHIRPS data were used to illustrate the climate extremes over the Ethiopian domain. The CRU TS series of data sets (CRU TS = Climatic Research Unit Time series) contain monthly time series of precipitation, daily maximum and minimum temperatures, cloud cover, and other variables covering Earth's land areas from1901 to 2020. The data set is high-resolution gridded datasets 0.5x0.5-degree resolution based on analysis of over 4000 individual weather stationrecords.

Among 27 precipitation frequency and intensity induces, a total of six indices were selected based on their relevance to understand the nature and vulnerability to climate extremes and to suggest feasible sectoral adaptation options in Ethiopia. Accordingly, Consecutive dry days (CDD), Consecutive wet days (CWD) were selected to illustrate the duration of dry and wet conditions, and the frequency of days with very heavy precipitation (daily precipitation ≥ 20 mm; R20mm) (R20mm) for intensity of Maximum 1-day precipitation (RX1day), Maximum 5-day precipitation total in mm (RX5day), and Simple Daily precipitation Intensity Index (SDII) intensity indices were used to determine the extremes intensity. Besides, various statistical methods such as REOF variability analysis, parametric and non-parametric trend analysis (regression, TEOF, Mannkedall test), composite analysis were employed to see how these climate indices changed, and wavelet analysis to understand the periodicity of these extreme events across the country.

A climate model is a numerical representation of the climate system, and thus not a perfect description of the system. The description of the physical laws governing the climate system differs between models. The model complexity differs between climate models, some models include more processes than others. This means that all climate models will give different results. The size of these differences can be large or small depending on model, region, season, variable etc. A model may perform well for some region/ season/ variable and worse for another, while another model performs well for yet another region/season/variable. The usual way to handle these differences is to use model ensembles. In this report three general climate model ensembles (Norwegian Climate Centre (NCC) NorESM1-M model/NCC-NorESM1-M, Hadley Centre Global Environment Model/HadGEM2-ES, and Max Planck Institute for Meteorology Earth System Model/MPI-ESM-MR) with rcp2.6 and rcp8.5 concentration pathways, which were then down gridded using two RCMs (ICTP regional climate model (RegCM4.7), and Climate Service Center Germany (GERICS), both CORDEX members) were employed. Thus, a total of 18 datasets were analyzed.

The evaluation team has exhaustively reviewed and thematically analyzed the national and international frameworks, policies and guidelines such as Climate Resilient Green Economy (CRGE), Growth and Transformational Policy (GTPI & GTPII), Nationally Determined Contribution (NDC), Ethiopia's NAPA, ten-year economic development plan (2021-2030), climate sensitive sectors policies and reports. Moreover, the view of Environment Protection Authority experts was captured and used to triangulate various data sources.

4.2. Analysis of climate change and variability

Analysis of past and future climate trends strongly points towards a year-round warming effect across Ethiopia (Conway and Schipper, 2011). The mean annual temperature has increased by 1.3 °C between 1960 and 2006 and is projected to increase up to 1.8 °C by the 2050s and 3.7 °C by the end of the century, under a high-emission scenario (RCP8.5). Most climate change models predicted an increase in temperature from 2.1°C in 2050 to 3.4°C by 2080 (FDRE, 2007). As Elshamy et al. (2009) argued, temperature will increase over the upper Blue Nile ranging from 2°C to 5°C at the end of the 21st century under the A1B scenario compared to a 1961–1990 baseline. Under this scenario, the region would be prone to evaporation and cause moisture stress (Conway and Schipper, 2011). The country exhibited a high level of spatial-temporal variability and uncertainty in precipitation and that is projected to continue. Hence, there is a high prospect of frequent and severe droughts and floods (Temesgen, Hassan and Ringler, 2011). About five major drought events have been recorded since 1980 (Araya et al., 2011; Bachewe et al. 2015. In southern, southwestern, and southeastern Ethiopia small rainy season and main rainy season rainfall decreased from 15-20% between the 1970s and 2000s. The reduction of rainfall by 15% to 20% could remarkably undermine crop and livestock production due to scarcity of water and moisture stress (Funk et al., 2012). Hence, it is possible to posit that recurrent drought has become the norm rather than the exception in affecting all walks of life (NMA, 2007; Araya et al., 2011; Viste, Korecha, and Sorteberg, 2013; Bachewe et al. 2015).

The impact of climate change and extremes in developing countries like Ethiopia would be unmistakable given the existence of exacerbating factors on the ground such as high population, traditional agricultural practice, weak institutional capacity,

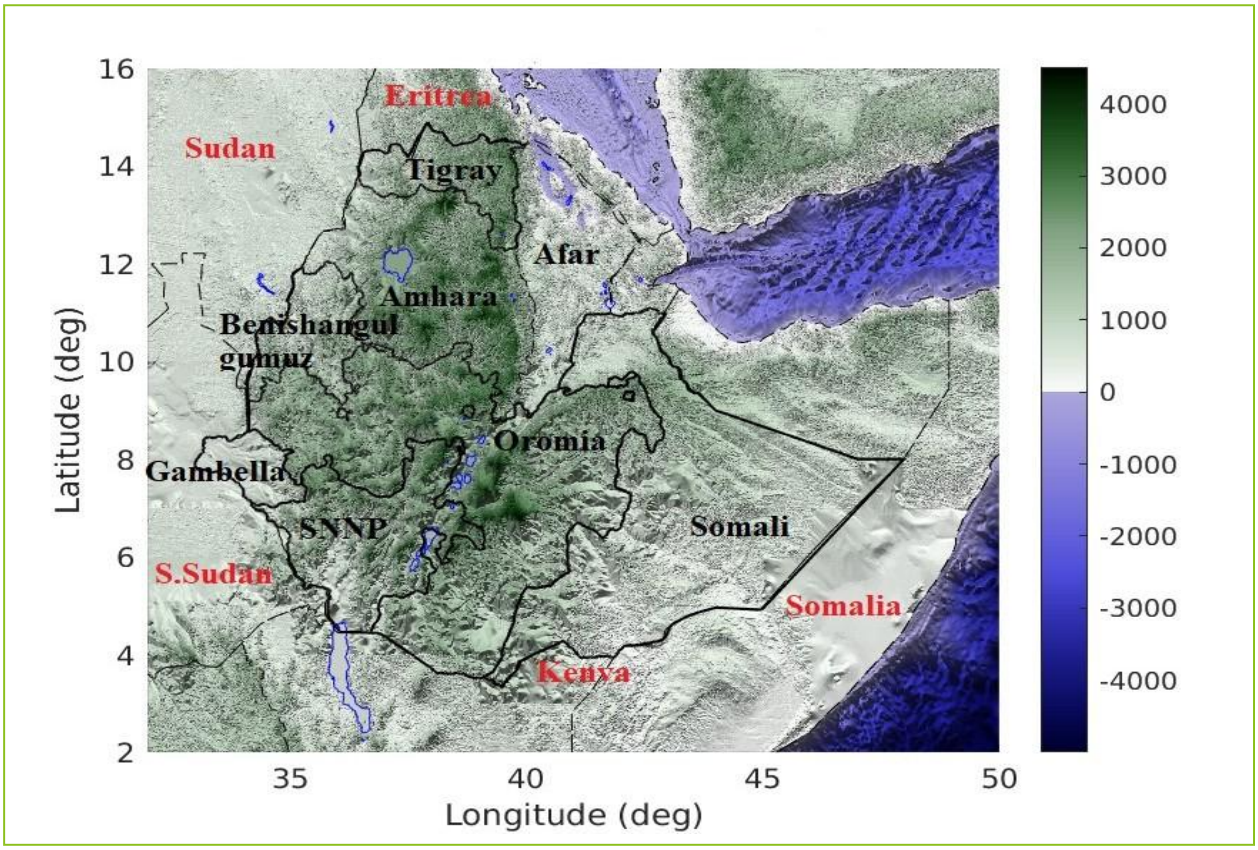


Figure 101 Topographic map of Ethiopia with a spare distribution of Rain-gauge stations

Inadequate basic infrastructure, and political instability (Mitiku et al., 2012; Syed, 2009; Devereux et.al., 2008).

According to the Climate Change Vulnerability Index, Ethiopia ranked seventh among countries at risk from the impacts of climate variability (Maplecroft, 2015). This vulnerability largely emanates from its low adaptive capacity and high exposure to climate extremes. Besides, the national economy is heavily dependent on agriculture, which contributes 40.2% of GDP, employs 80% of its population, and accounts for 70% of export earnings (African Development Bank (AfDB), 2015). In Ethiopia, climate change and extremes such as drought, erratic rainfall, flood, and temperature increase have been affecting soil fertility and moisture availability, cropland suitability, and grazing land carrying capacity. It facilitates land use conversion at the expense of the ecosystem welfare (Mbow et al., 2019). Climate change and extremes collectively put the poor in poverty and chronic food insecurity. It further increases the sectors' vulnerability and becomes bottlenecks to adapt and cope with the impact of climate change and ensure national sustainable development and food security. The recent drought in 2015/16 affected millions of people (Tadesse and Alemayehu, 2019), worsened food insecurity, and remarkably reduced the national GDP (IFPRI and UNDP, 2019). The following La Nino induced flood killed 136 people, affected 195,987 people, and destroyed 33,446 cattle.

Climate change and variability could be also explained by dry spell and cold spell events and impacts on the biophysical environment at global and local level (Zhao and Running, 2010; Jiao et al, 2021; Zscheischler et al., 2014; Xu et al, 2021 Zhang, Keenan and Zhou, 2021; Bastos, 2014; Zscheischler, et al., 2014).

4.2.1.Precipitation Extremes

There is a general consensus within the climate community that changes in the frequency and severity of extreme climate events could exacerbate the impact of climate on elements at risk. The analysis of precipitation and temperature is crucial in flood and drought monitoring and to suggest context-specific adaptation measures. Extreme indices assess climate variability and extremes of daily temperature and precipitation above or below specific thresholds. International research groups (the Expert Team on Climate Change Detection Monitoring Indices (ETCCDMI) propose 27 extreme precipitation and temperature (Karl,1999, Peterson,2001). This study used six extreme indices to analyze the spatiotemporal variation and wet season daily precipitation trend over Ethiopia.

Table 63 Description of extreme precipitation indices

Classifications	Category of indices	description	Unit

Precipitation Duration	Consecutive dry days (CDD)	Consecutive dry days (CDDs) represent, the maximum number of days with precipitation less than 0.1 mm is an effective measure of extreme precipitation and seasonaldroughts	day
	Consecutive wet days (CWD)	Maximum number of consecutive days with precipitation amount at least 1 mm. This climate index is a measure of precipitation, with high values corresponding to a high chance of flooding.	day
	Number of days with very heavy precipitation ≥ 20 mm (R20mm)	It is a measure of heavy precipitation, with high values corresponding to a high chance of flooding. An increase of this index with time means that the chance of flood and its adverse effect is certain.	day
Precipitation Frequency	Maximum 1-day precipitation (Rx1day)	Maximum of one day precipitation amount in a given time period explains the likelihood of heavy precipitation and flooding.	mm
	Maximum 5-day precipitation total in mm (Rx5day)	Maximum of five day precipitation amount in a given time period corresponding to a high chance of flooding. An increase of this index with time means that the chance of flood conditions will increase.	mm
Precipitation Intensity	Simple Daily precipitation Intensity Index (SDII)	SDII for rain is defined as the ratio of annual or seasonal total rainfall to the number of days during the year or season when rainfall occurred (rain day : daily rain >= 1mm)	mm/day

Sources: (Karl,1999, Peterson,2001)

Accordingly, Figure 4-102illustrates variations in seasonal and spatial distribution of continuous dry days (CDD) and continuous wet days (CWD) between 1990–2020 in Ethiopia. The number of CDDs increases from northwest towards northeast and southeast during June, July, and August (JJA season (Figure 4-102a). Northwest and southeast regions exhibited higher numbers of CDDs during March, April, and May (MAM) (Figure 4-102b). The northeast, northwest and southeastern tips of Ethiopia experienced higher CDDs than other parts of Ethiopia in September, October, and November (SON) (Figure 4-102c).In general the highest CDDs were observed in the southeast parts of the country followed by the northeast. Therefore, particularly the southeast and northeast parts of Ethiopia have been affected by soil moisture stress, shortage of pasture and water, as well as hazard which could be triggered by dry weather conditions.

AsdepictedinFigure 4-102d-f thenumberofCWDsfrom1990-2020were0to18days.The

longest wet day's period was over the northwest part of Ethiopia during JJA. JJA is the main rainy season for this part of the country. CWDs have been increasing from the southeast to northwest part of the country JJA (d). CWD distribution was relatively uniform during MAM throughout the country. However, slightly higher CDD were recorded in the southwest part of the country. Unlike the CDD event; the northwest and west parts of the country experienced the highest number of rainy days during (SON). The analysis result depicted that Figure 4-102(a and c) and (d and f) CDD and CWD happened in different parts of Ethiopia during the same season. This is partly due to large scale atmospheric and oceanic circulation (Wang et al., 2019; Kenyon and Hegerl, 2010; Willems, 2013) and topographic features of the country. The contributing atmospheric and oceanic circulation indices for the extreme precipitation, including Multivariate ENSO Index (MEI), Southern Oscillation Index (SOI), Northern Oscillation Index (NOI), North Atlantic Oscillation (NAO), Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO).

Figure 4-102: Precipitation indices (CDD, CWD and R20 mm in days) from 1990–2020 in Ethiopia for JJA (a), MAM (b), and SON seasons (c) consecutive dry day (CDD) of JJA (d), MAM and (e) SON season (fThe frequency of very heavy precipitation (daily precipitation ≥ 20 mm; R20mm) is illustrated in Figure 4-102g-i. Generally, the western part of the country received a greater number of days of heavy precipitation than the northeast, east and south part during June, July and August (JJA). However, the southwestern part displayed a slightly higher number of days during (MAM). MAM and SON displayed a similar pattern of intense rainfall days. Thus, it seems flood is the most important risk in the western and southeastern parts of Ethiopia. However, sheet flood and gully formation are a serious problem particularly in the highlands of Ethiopia due to land degradation and rugged topography (Abebe et al., 2022; Birhanu et al., 2016).

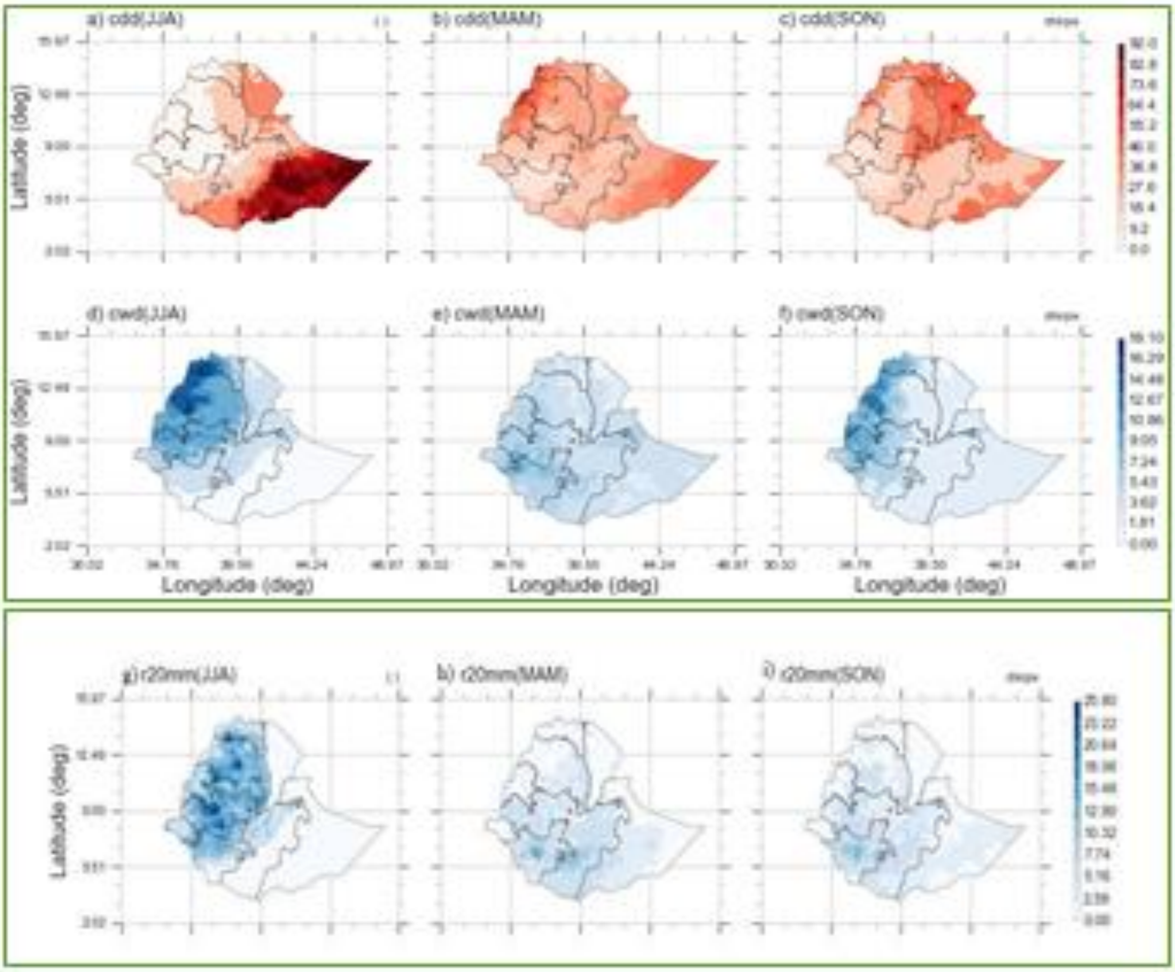


Figure 103 Mean climatology of rainfall intensity indices (SDII, rx1day and rx5day in mm/day) over Ethiopia. SDII for JJA (a), MAM (b), and SON seasons (c), Maximum1-day precipitation of JJA (d), MAM (e) and SON season (f) and rx5day for JJA (g) MAM (h) SON (i) d

Figure 107 illustrates Simple Daily Precipitation Intensity Index (SDII). SDII defined here as seasonal total rainfall to the number of days during the season. In Ethiopia about to 44 mm mean rainfall was recorded per day during the study period. The western, southwestern and central part of Ethiopia received higher intensity of rainfall than south, east and northeast parts during JJA months. During the MAM months the southern and central parts received more intense rainfall. In SON seasons the eastern tip and southern and southeast highlands received more intense rainfall. It seems different parts of Ethiopia have been experiencing rainfall >1mm in different seasons d-f shows (R×1day in mm/day) for JJA (a), MAM (b), and SON seasons (c). The intensity of rainfall in mm/day increases from 0 to 67 mm which is more than SDII value. The intensity of rainfall increases from central to the Northwest tip part of the country. This result indicates that the area is highly prone to flooding during the JJA season. The southwestern part of Ethiopia receives more intense rainfall during MAM and more flooding will be evident during this season. Similarly, the western and southwestern part of Ethiopia received higher amounts of rainfall in mm/day during SON.

The highest amount of rainfall recorded in five consecutive days during the studied periodwas104mm.Ingeneral;themaximumfivedayprecipitationintensitywashighest in the central and southern part of the country. However, the five day maximum rainfall was less intense in south, southeast, northeast and the northwestern peripheral parts having less extreme precipitation record during JJA season. However, the south parts of Ethiopia display intense precipitation during spring and autumn seasons.

Generally, Ethiopia received the highest mean annual, frequent and intense rainfall during JJA mainly in the west, southwest parts of the country. Likewise, annual mean, frequency and intensity of rainfall were higher in the south and southwestern parts of Ethiopia. While, in SON the intensity and frequencies of rainfall were higher in the southern part of the country. With an increasing frequency and intensity of rainfall trend coupled with rugged topography and land degradation, the flood has been causing serious adverseimpacts,particularlyinwestern,southwestern,andsouthernpartsofEthiopia.

4.2.2.Precipitation Extremes Trend

The JJA CDDs trends have been decreasing in most parts of the northwest, central and southwestern Ethiopia .Likewise, a decreasing trend of CDD was exhibited in most parts of the southeastern, south, and southwest parts of Ethiopia during SON. Central Ethiopia showed a decreasing CDD trend during MAM season. On the contrary, CWDs have been increasing in the central and southern part during JJA. Similarly, in MAM the southeastern and northwest and in SON the southeast, south, central and northwest tip regions of Ethiopia also experienced an increasing trend of CWDs (Fig. 4. 4. d-f). The wet condition (r 20 mm) has been increasing and decreasing in the southeastern and western part of Ethiopia respectively. During September, October and November, the southeast,south,central and northwest tip regions also illustrated increasing. The result confirms r 20 mm increased in southeastern Ethiopia during SON. On the contrary, the western part exhibited a decrease of trend r 20 mm during the same period (Figure 108).

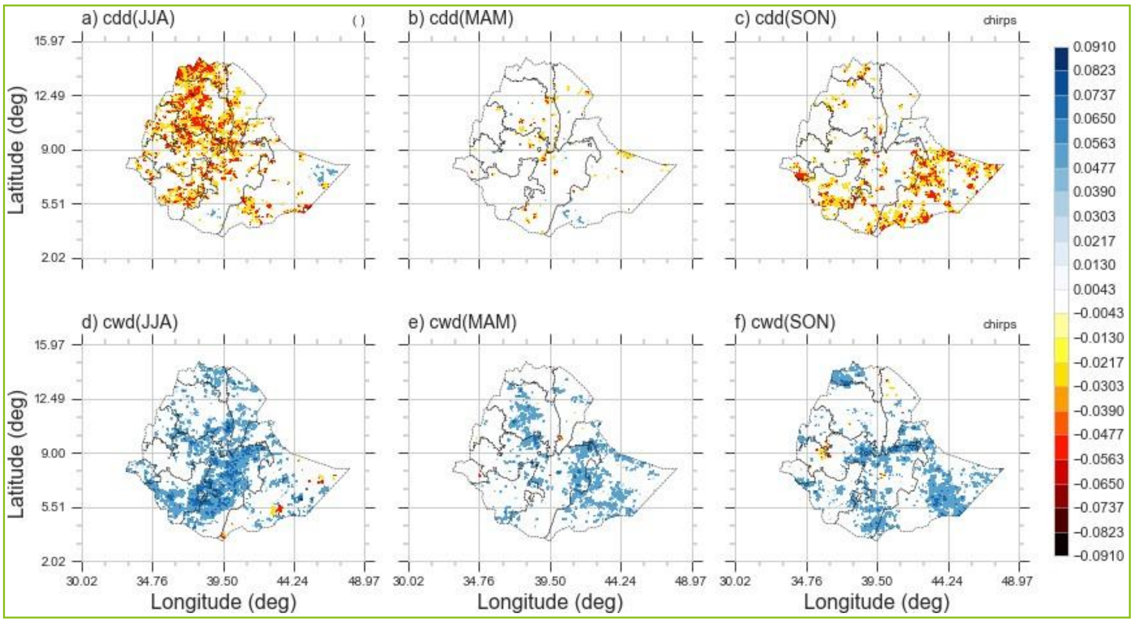


Figure 104 Trend of rainfall intensity indices of CCD over the period of 1990–2020 in Ethiopia for JJA (a), MAM (b), and SON seasons (c) and CWD of JJA (d), MAM and (e) SON season (f)

The frequency of very heavy precipitation (daily precipitation ≥ 20 mm; R20mm) trend showed both an increasing and decreasing trend. An increasing trend of rainfall was observed in southwest and south highlands during JJA. In SON, an increasing trend of rainfall mainly was recorded in the west, south west and north east. In MAM, an increasing trend was observed in the south, southwest and eastern tip. However, a decreasing trend of rainfall was also identified in the central regions extending from north to central region of Ethiopia in JJA and Eastern parts in MAM and central region in SON. More specifically, the CDD trend decreased over the Amhara region during JJA. While, the event shows an increasing trend in the east and southern part of Oromia region during JJA. The CWD trend has been increasing in the Somali region during JJA and MAM seasons. The intensity trend showed an increasing trend over southern SNNP, Western Oromia during JJA, West and South eastern Oromiya, East Gambella over many parts of SNNP during spring season. In the Autumn season, much of the south west parts of Ethiopia have displayed an increasing trend whereas northern and eastrn parts have a decreasing trend during spring and Autumn seasons. Generally, the spatial and seasonal distribution of trend of CDD and CWD duration as well as rainfall frequency increasing and decreasing trends confirms that dry and wet extremes could increase the sectors' vulnerability and erode adaptive capacity.

. Figure 109 illustrates the simple daily rainfall intensity index (SDII) trend during JJA, MAM and SON seasons. SDII showed an increasing trend over south Benishangul, northwest and western Oromia in spring and autumn seasons. Decreasing trend was observed over much of Amhara region, north, north west Oromia, central Oromia during JJA. East Oromia, Somali and Central Ethiopia and north Somali region display a decreasing trend during spring and autumn season. Rx1 days showed an increasing trend over west and south Oromia, central and west Somali in JJA seasons. West Ethiopia showed an increasing trend in spring and autumn. Decreasing trend was observed over north central Ethiopia north and east Somali and central during Spring and Autumn.

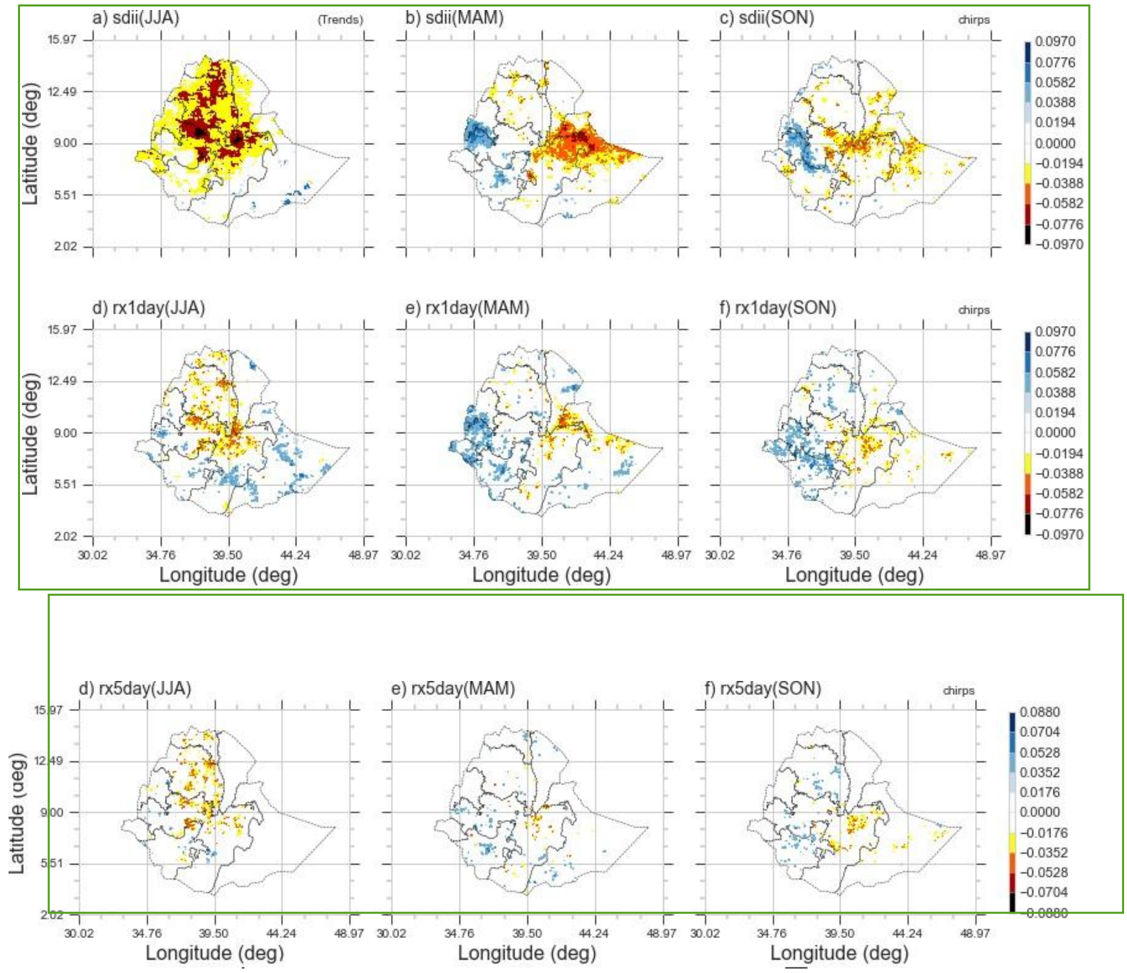


Figure 105 Trend of rainfall intensity indices of SDII over the period of 1990–2020 in Ethiopia for JJA (a), MAM (b), and SON seasons (c) and RR1 of JJA (d), MAM and (e) SON season (f)

Maximum 5-day precipitation total in mm/day show a decreasing trend during JJA in central and north parts and a slightly increasing trend in the south west. The west and south west regions showed increasing trends during MAM and decreasing trend in the central area. SON displayed an increasing trend in the west and north and a decreasing trend in the central regions of Ethiopia. The precipitation intensity index trend of SDII generally increases in west Ethiopia during spring and autumn. However, SDII has been decreasing in the north, central and eastern parts of Ethiopia during the summer and spring seasons. The R×1mm day extreme event trend shows an increasing trend in the south, and southeast region parts of Ethiopia during summer and west region during spring and autumn. Whereas, the R×1mm day extreme event has been decreasing in the north and central parts of the country during summer. The eastern and central regions experienced a decreasing trend in the spring and autumn seasons. R× 5 mm days were less intense compared to R×1 mm days and had less area coverage over the south in summer and, west during spring and autumn.

4.2.3.Temperature Change

The mean annual temperature has, for example, increased by 1.3°C between the years 1960 and 2006. This is estimated to be an average rate of 0.28°C increase in temperature per decade (Conway,2011) The increase in temperature in Ethiopia has been most rapid July through September at a rate of 0.32°C per decade (McSweeney, 2012).

Figure 4-106.shows the minimum and maximum temperature climatology of 120 years from 1901-2020. JJA minimum temperature decreases from southwest to northeast (Figure 4-106.). MAM minimum temperature was highest in the northeast and decreased towards southeast. SON season shows similar patterns of temperature with the JJA season. Overall, the mean minimum temperature is increasing over the past 120 years. The maximum temperature follows a similar spatial pattern with the minimum temperature (Figure 4-106d- f).

Figure 111 shows the minimum and maximum temperature from 1990-2020. JJA minimum temperature pattern shows similarity with that of 1901-2020.The mean minimum temperature of Ethiopia has been increasing by 0.002 °C per decade between 1901-2020. However, the mean temperature has increased by 0.02 °C per decade between 1990-2020. This confirms that the rate of minimum temperature increment has become faster in recent decades. Figure 4-106: The mean climatology of minimum and maximum temperature using CRU data, Minimum temperature of JJA (a), MAM (b), and SON seasons (c) and maximum temperature of JJA (d), MAM and (e) SON season (f) over Ethiopia during the period 1901-2020

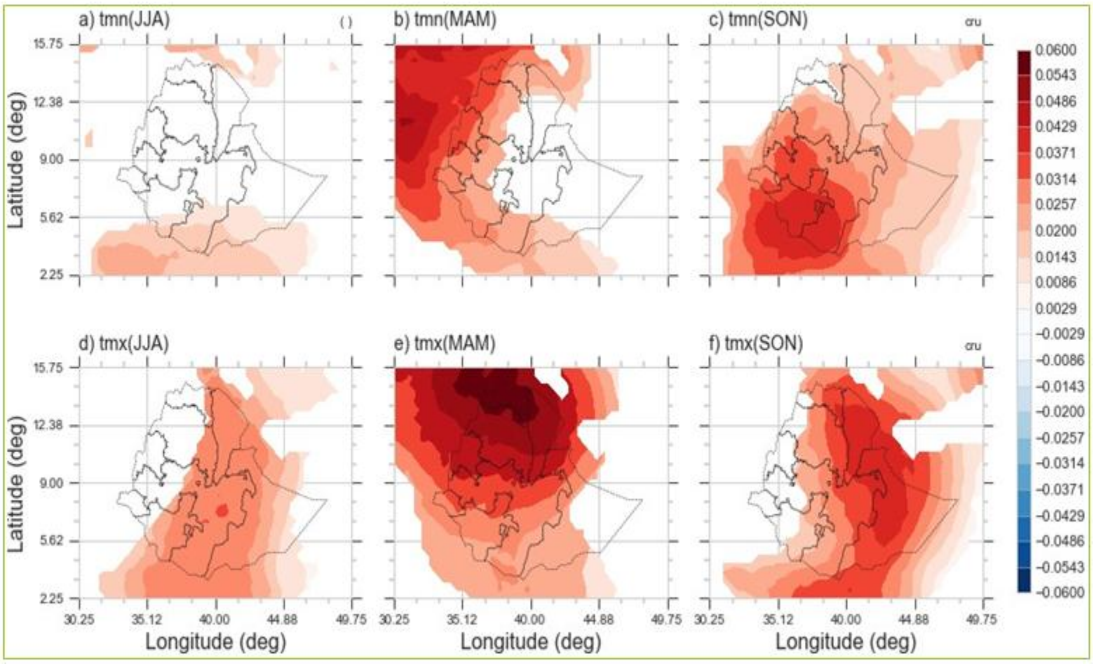


Figure 107 The temperature climatology of minimum and maximum temperature using CRU data, Minimum temperature of JJA (a), MAM (b), and SON seasons (c) and maximum temperature of JJA (d), MAM and (e) SON season (f) over Ethiopia during the period 1990-2020

4.2.4.Projection of Precipitation Extremes

Extreme precipitation events are major causes of severe floods and droughts worldwide. Therefore, scientific understanding of changing properties of extreme precipitation events is of great scientific and practical merit in the development of human mitigation of natural hazards, such as floods and droughts. The frequent occurrence of extreme weather and climate events such as heat waves, droughts, and heavy rainfall over the recent years is evidence of climate change (Alexander et al., 2006; Sillmann et al., 2013; IPCC, 2014; Alexander, 2016), which is linked to global warming. The special report of the Intergovernmental Panel on Climate Change (IPCC) on impacts of global warming of 1.5 0C estimates that global warming is likely to reach 1.5 0C between 2030 and 2052 relative to the pre-industrial levels. It sees emissions peak early, then fall due to active removal of atmospheric carbon dioxide (IPCC, 2018). The resultant response of climate systems will be depicted by features such as increased intensity of precipitation extremes, a sharp decline in the number of wet spell lengths, and an increase in dry spell lengths (Giorgi, Raffaele, Coppola, 2019). The unprecedented impacts of climate extremes threaten human health, economic stability, and the stability of natural and built infrastructure (Agha et al., 2020). Thus, characterizing the response of anthropogenic climate change, which results in extreme events at the regional or local level, is an imperative task.

Global and regional precipitation changes have been noted with substantial upsurge detected over Europe (Fischer, and Knutti, 2015; Papalexiou and Montanari, 2019), China (Jiang, 2011; Yuan et al., 2015) and the United States (Papalexiou and Montanari, 2019; Janssen et al., 2019; Akinsanola and Zhou, 2019). Africa is one of the most susceptible areas to climate variability and change (Niang et al., 2019). Positive trajectories in temperature have been observed and are projected to increase significantly across the continent (Niang et al., 2019; Collins et al., 2013; Ayugi et al., 2021). This will affect the broader population’s livelihoods that mainly rely on rain fed agriculture (FAO, 2019). Further, the projected increase in temperature will intensify moisture loss through amplified evapotranspiration and strengthen the occurrence of drought hazards (Peterson, Stott and Herring, 2012; Van Loon et al., 2016; Ayugi et al., 2020; Tan et al., 2020). Despite the widespread occurrence of extreme climate events, regional variation is noted due to complex physiographic features and processes, resulting in varying responses to the global-scale change (IPCC, 2019).

Figure 112 show projection of precipitation indices over Ethiopia under rcp 2.6 and 8.5 scenarios for CDD, CWD, R20 mm, SDII, Rx5 day and rx1 day illustrating the period, frequency and intensity of extreme precipitation over Ethiopia and the surrounding area. The projection is from 2020-2050 under RCP 2.6 and 8.5 scenarios for summer, spring and autumn seasons compared with the base period 1990-2020. RCP 8.5 is Business-as-usual or a worst-case scenario and RCP 2.6 is the most ambitious pathway. The assumption in RCP 2.6 sees emissions peak early, then fall due to active removal of atmospheric carbon dioxide. In this report both scenarios were used to describe future precipitationextremes.

Figure 112 depicts CDD (continuous dry days) and NCDD (maximum number of continuous dry days) periods. Generally, CDD shows decreasing precipitation periods over all parts of Ethiopia with intense reduction over the eastern parts during spring season. The number of continuous dry days decreases over many parts of Ethiopia in all the seasons except the north east and south east parts which show no changes during summer season. On the contrary, CDD decreases towards the east (-4 to - 12/day) during spring season with the highest reduction over the eastern part of the country. Autumn season also shows a decreasing CDD over all parts of Ethiopia with a more reduction in the east. Maximum continuous dry days also show a decreasing trend over most parts of Ethiopia except a slight increase over north east and south eastern tip during spring season. Spatial distribution of precipitation extreme patterns of summer, spring, and autumn seasons of CWD and NCWD illustrated

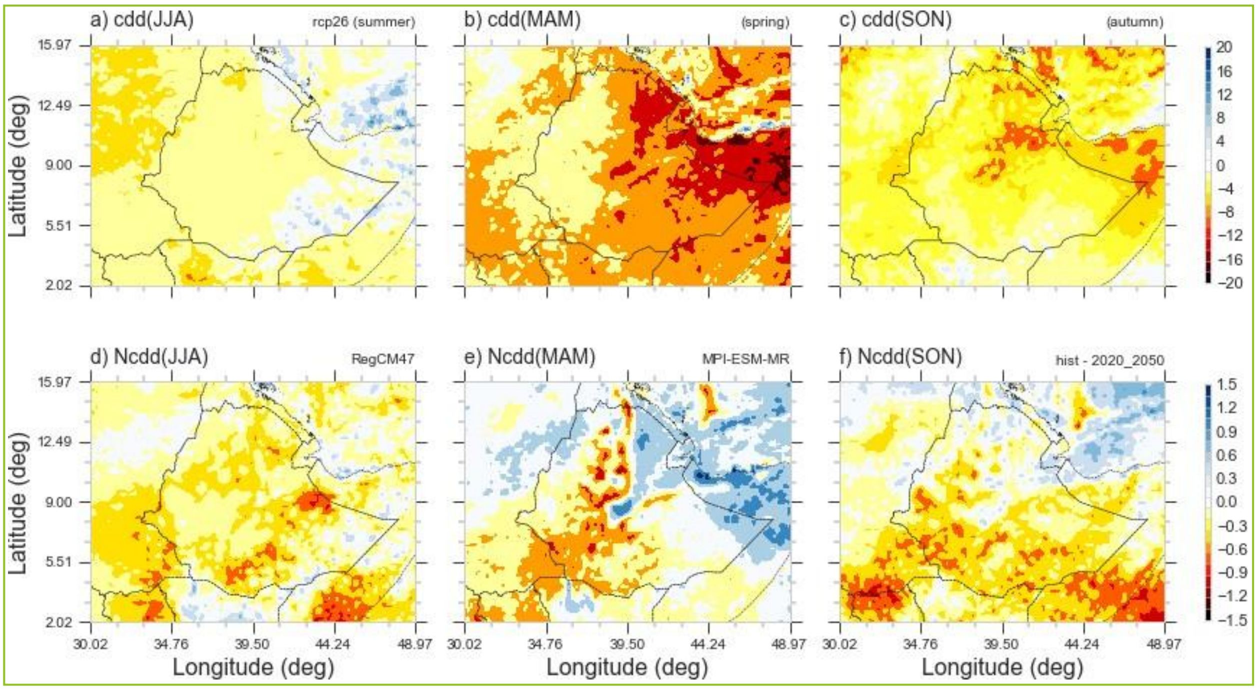
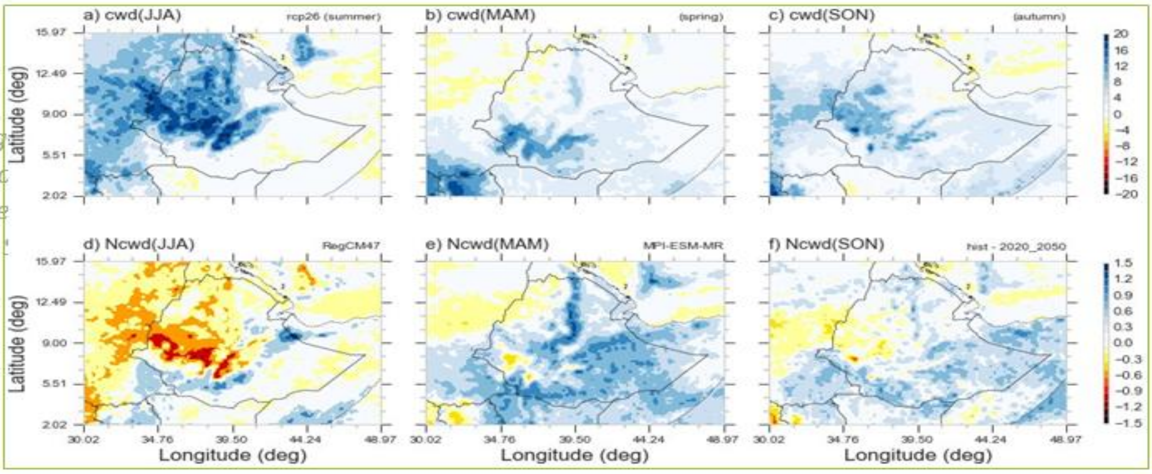


Figure 108 Spatial distribution of seasonal CDD projection over Ethiopia under RCP 2.6 scenario from 2020 to 2050 for a) Summer b) spring C) autumn and Maximum CDD d) Summer e) spring f) autumn

in Figure 113 generally, during summer season precipitation increases against the baseline period over central, south and North West, and west parts of the country. However, south, east and south eastern parts do not show changes. The projection of CWD trend shows an increasing precipitation in the western part of Ethiopia during 1990-2020. The southwest CWD extreme precipitation duration during spring season increased. However, the autumn season duration decreases. The maximum CWD increased during thespringseason. whereasthewesternarea CWD shows a decrease in autumn season.



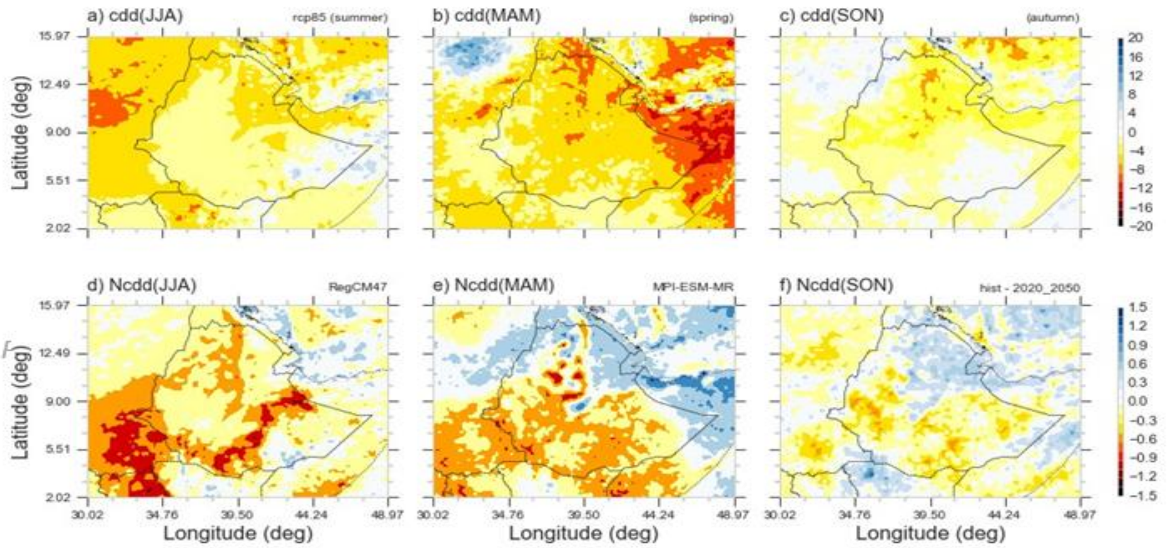


Figure 109 scenario from 2020 to 2050 for a) Summer b) spring C) autumn and Maximum CDD d) Summer e) spring f) autumn

Figure 114 illustrates CDD spatial distribution under RCP 8.5 scenario. In both RCP scenarios, CDD show decreasing values in all the three seasons. Ncdd shows an increasing value over north east during spring and autumn seasons. CWD under RCP 8.5 and RCP 2.6 scenarios display similar results.

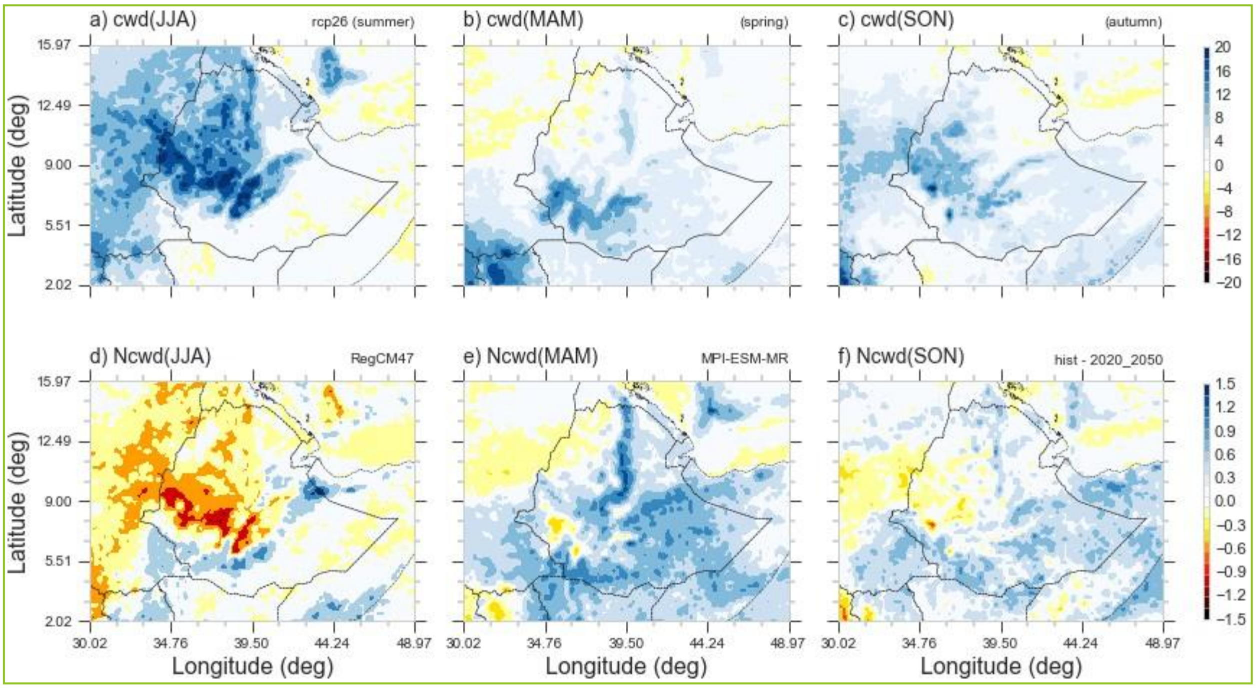


Figure 110 Spatial distribution of seasonal CWD projection over Ethiopia under RCP 2.6 scenario from 2020 to 2050 for a) Summer b) spring C) autumn and Maximum CWD d) Summer e) spring f) autumn

High intensity of CWD was observed over the western and central parts of the country compared with the historical record during summer. CWD in the southern part displayed a high amount of CCD during spring and autumn. Generally, the projected precipitation covers a small area but very intense CWD.

Generally, unlike the historical analysis result, the R× 20 mm projection result shows a decreasing trend almost in parts of Ethiopia (Fig. 4.13). The historical record confirms that Rx 20 mm has increased in the southern part of SNNP and Oromia summer season as well as west Oromia and SNNP during spring and autumn (Fig. 4.4). Unlike the historical recorded analysis, the projection of Rx20 mm is projected to increase in the Amhara region in the summer season. South Oromia showed an increasing trend over the south during summer and spring seasons.

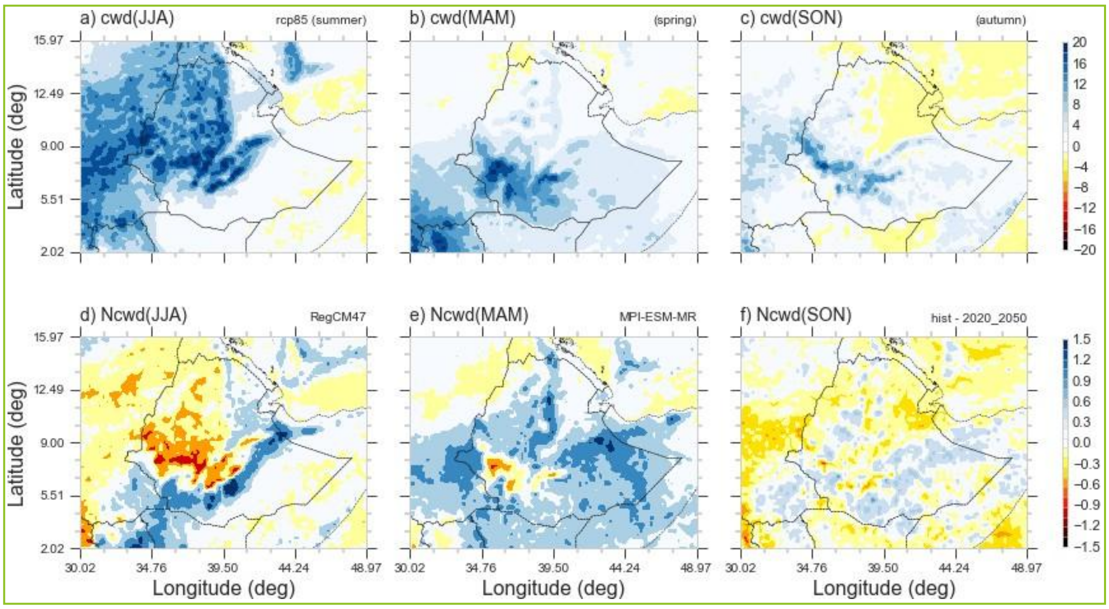


Figure 111 Spatial distribution of seasonal CWD projection over Ethiopia under RCP 2.6 scenario from 2020 to 2050 for a) Summer b) spring C) autumn and Maximum CWD d) Summer e) spring f) autumn

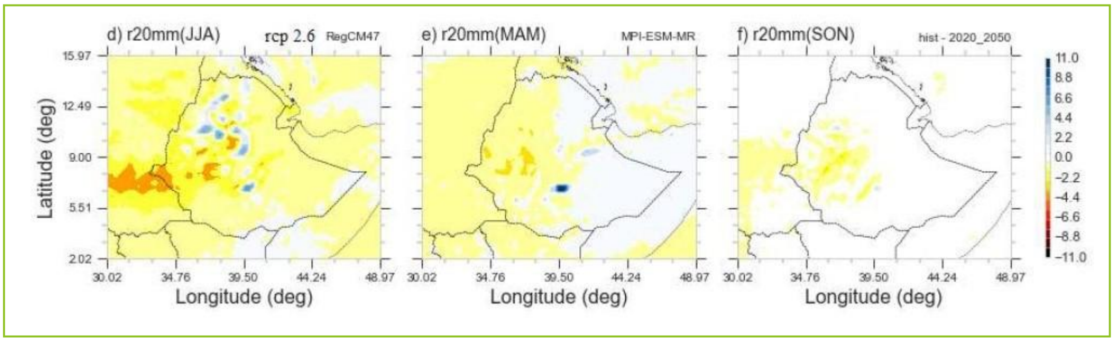


Figure 112 Spatial distribution of seasonal Rx 20 mm trend projection over Ethiopia under RCP 2.6 scenario from 2020 to 2050 for a) summer b) spring C) autumn and maximum CDD d) Summer e) spring f) autumn

Historical trend of SDII shows an increasing trend in the west parts of Ethiopia Figure 116. However, SDII projection under RCP 2.6 scenario illustrated a decreasing trend except a slight increase in the north east and south east regions of Ethiopia during spring season. Similarly Rx 1 day values display a decreasing trend throughout the country except slight increments in the north east and south east of Ethiopia during spring and autumn.

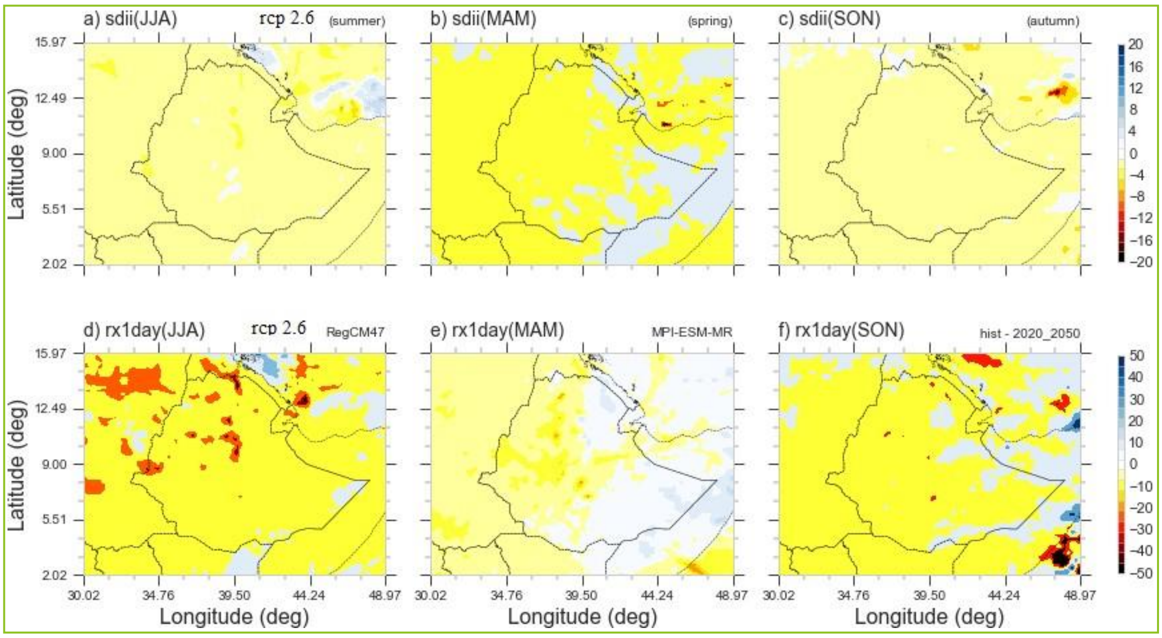


Figure 113 Spatial distribution of seasonal SDII projection over Ethiopia under RCP 2.6 scenario from 2020 to 2050 for a) Summer b) spring C) autumn and Rx1 day d) Summer e) spring f) autumn

4.2.5.Temperature Projections

The global climate is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse (heat-trapping) gasses emitted globally and on the remaining uncertainty in the sensitivity of the Earth's climate to those emissions. With significant reductions in the emissions of greenhouse gasses (GHGs), global annual averaged temperature rise could be limited to 2°C or less. However, without major reductions in these emissions, the increase in annual average global temperatures, relative to preindustrial times, could reach 5°C or more by the end of this century (WBG, 2021). According to WMO latest predictions the annual mean global near-surface temperature for each year between 2022 and 2026 is predicted to be between 1.1°C and 1.7°C higher than pre-industrial levels (the average over years 1850-1900) (WMO,2022).

Figure 117 illustrates minimum and maximum extreme temperature projections under RCP 2.6 and rcp 8.5 scenarios. In all the seasons, both minimum and maximum temperature extremes show an increasing trend with 1.5 and 2.00 0c under rcp 2.6 and 8.5 scenarios respectively. The minimum temperature is highest over the south eastern and north western under rcp 2.6 and south eastern and north western area of Ethiopia under rcp 8.5 scenarios during spring season. Maximum temperature is also highest during spring over southern parts of the county under both scenarios.

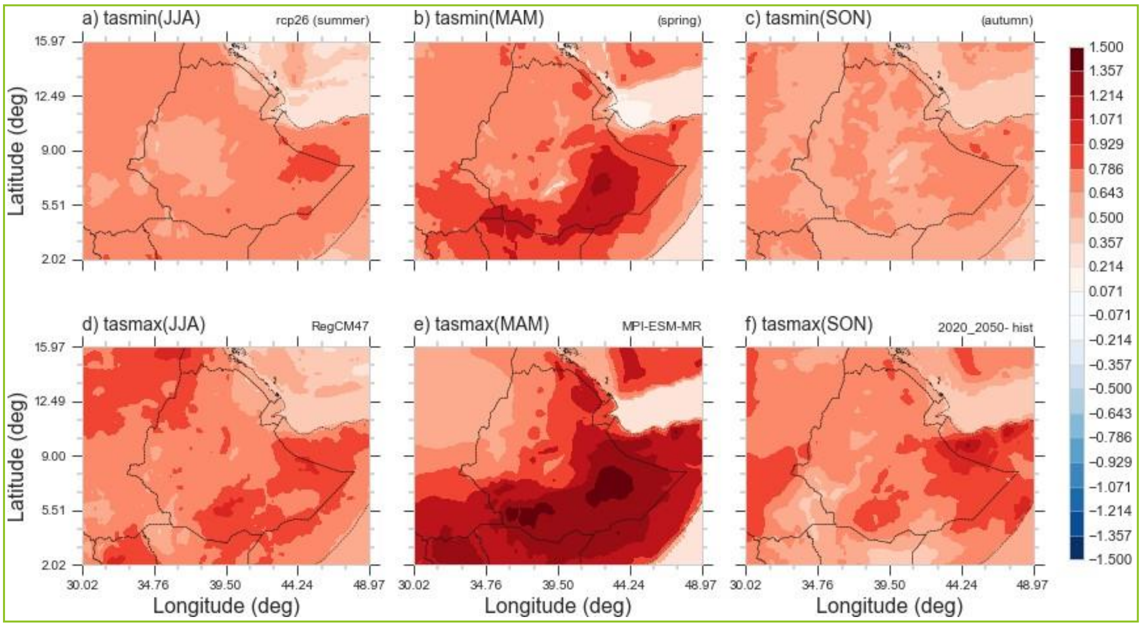


Figure 114 Spatial seasonal minimum extremes temperature distribution scenario from 2020 to 2050 for a) Summer b) spring C) autumn and maximum temperature for d) Summer e) spring f) autumn seasons over Ethiopia under RCP 2.6 senario

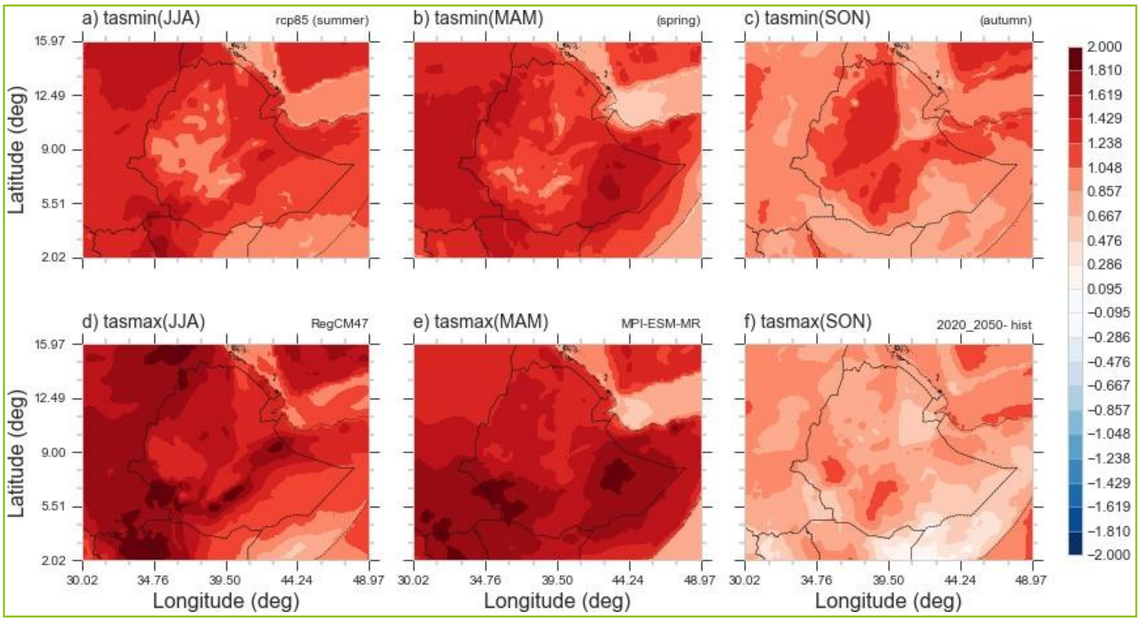


Figure 115 Spatial seasonal minimum extremes temperature distribution scenario from 2020 to 2050 for a) Summer b) spring C) autumn and maximum temperature for d) Summer e) spring f) autumn seasons over Ethiopia under RCP 8.5 scenario

To conclude, In Ethiopia minimum and maximum temperatures under RCP 2.6 and 8.5 are expected to be increased from 1.5 to 2.00 °C. However, the south, southeast and west parts experience intense temperature increments than the rest. CWD shows an increasing trend over the west and south parts of the country. However, SDII, Rx20 mm and RX 1 day decreased over most parts of the country.

4.3. Vulnerability and adaptation in major climate sensitive sectors

4.3.1. Agriculture

Agriculture being the mainstay of the economy, the government of Ethiopia (GOE) has identified key priority intervention areas to increase the productivity of smallholder farms and expand large-scale commercial farms to ensure food security. Accordingly, the top priorities of the government are developing small and large-scale irrigation, financing agricultural inputs, increasing crops and livestock productivity, fostering mechanization, reducing post-harvest loss, developing a research-based food security system, and enhancing natural resource management. The Home-Grown Economic Reform aspires to boost the agro-processing sector as a key engine to spur economic growth. Such policy interventions have raised the productivity of both crop and livestock sectors. The government has established the Agricultural Transformation Agency (ATA) to address systemic bottlenecks by enhancing the capability of the Ministry of Agriculture (MOA) and other implementingpartners.

To promote large scale commercial farming, the Ministry of Agriculture (MOA) has created the Ethiopian Agricultural Land and Investment Administration Agency. The Agency is responsible for increasing agricultural productivity and job employment through technology transfer and agricultural financing from investors. The Reform endeavors to tackle the structural and institutional bottlenecks affecting agricultural performance such as challenges related to inputs, service delivery, vague land lease rights, marketing, and financing. The ten-year economic development plan (2021-2030) of the government puts agriculture at the center of priority sectors and the sector is projected to show a 6.2% average annual growth. The Plan aims at boosting agricultural export revenues and substituting imports by reducing production costs and harnessing a climate resilient green economy. Specifically, the government has focused on mitigating land degradation and environmental pollution through afforestation, electrification, and adoption of energy saving technologies.

4.3.2. Impact of Climate Change on Agricultural Future Periods

Climate change and extremes seriously affected African agricultural production and it will continue to be a threat in the future (Thornton, 2010). In east Africa, 72% of wheat crop yield, 45% of maize, rice, and soybean, 15% to 10% of root crops, such as sweet potato, potato, and cassava, and 40% of tea and coffee yield decline is expected due to climate change (Adhikari et al., 2015). Climate change and extremes could also create favorable conditions for the proliferation of pest, weed, crop & livestock diseases (such as tick and tick borne diseases), and infectious diseases such as LSD, anthrax and black leg. There is growing evidence confirming that climate change has increased malaria epidemic and other zoonotic diseases. Climate change is projected to increase malnutrition with the highest toll expected in children (Niang et al., 2014).

Ethiopia is one of the most vulnerable countries to climate change and extremes. The futureclimatechangeprojectionssuggestthattemperaturewillriseandrainfallvariability will increase with high unpredictability. Agriculture is extremely vulnerable to these changes, with concerns that the yields of the main cereal crops will be adversely affected and result in food insecurity in the country. The 2015 El Niño reduced crop and livestock production especially in drought prone areas of Ethiopia country (Chichongue et al., 2015). The key vulnerability indicators of Ethiopia's agriculture to climate change and extremes are recurrent drought and flood. Besides, heavy dependence of Ethiopia’s economy on rain-fed agriculture, low agricultural input, weak technological application, rugged topographic features, high poverty level, inadequate infrastructures, high population pressure and poor health service and facilities further exacerbated its vulnerability to climate change and extremes.

In pastoral and agro-pastoral communities in drought-prone areas, ever rising temperature, recurring drought conditions and erratic rainfall present the most significant impact on the agriculture sector and hence, food security. The southern and eastern parts of Ethiopia including Afar, Somali, and Oromia often experience severe drought and water scarcity problems. Extreme climate events cause successive droughts and frequent floods have strongly affected poverty, food security, livelihood status, and the human capital communities.

Ethiopiaconfrontedmanyadverseimpactswhicharemanifestationsofvariableclimate. Yet there are indications by which these impacts will continue to influence the socio-economic activities of the community on a larger scale. The northern, southern, and south-eastern dry land regions of Ethiopia have repeatedly faced increased frequency of meteorological drought episodes, famines, and outbreaks of diseases which are believed to be linked with climatic change. The droughts have highly impacted the agriculture of the country and brought about the loss of crops, animals, and above all the loss of millions of people. Flood hazards have increased in recent decades.

The livestock sector is sensitive to climate change and climate stress and shocks. Climate change and extremes could cause rangeland degradation and hence, shortage of pasture and water, infestation of invasive species, gully formation and decline production and productivity, livestock weight loss, delay Calvin at first and Calvin in between, and reduce the livestock market value. It further triggered secondary hazards such as prevalence of livestock diseases, resource-based conflict, worsen food insecurity, increased school dropout (Demissew, 2022; Zelalem et al., 2009). Historically, climate extreme events such as rain failure, floods, drought, cold spell, dry spell and untimely rainfall adversely affect the country's natural and environmental system and threaten the performance of the agriculture and economy as a whole and cause loss of livelihoods and food and nutrition insecurity for households mainly in marginal and less productive lands in thecountry.

4.3.3.Adaptation Options in the Agriculture Sector

In Ethiopia the government and individual farmers have been implementing various climate change adaptation strategies to reduce the impact of climate change. This includes; diversity crop varieties, changing crop variety, changing planting dates, mixing crop and livestock production, agro-forestry, adoption of drought tolerant crop variety, grow early maturing crop varieties, soil and water conservation, shift from livestock to crop production, income diversification, seasonal migration, water harvesting, irrigation, fertilizer application, changing cropping densities, pesticide application are among the common adaptation strategies farmers carry out in response to climate change (Bradshaw et al., 2004; Nhemachena and Hassan, 2007; World Bank, 2012; Deribe 2015). Whereas, destocking, changing herd composition, temporary migration, livestock diversification, shifting to drought tolerant livestock species, improving livestock feeds, apply cut and carry feeding are climate change strategies in the livestock sector. The extent to which adaptation strategies are implemented varies among individual farmers depending on their capacity and willingness to adopt (Krishna, 2011). However, in general, Ethiopia's recent development plan aspires to increase the performance of the sector in different ways. Specifically, the government has planned to foster infrastructural development, provision of health and education, creation of market linkage, and enhancing rural financing for animal fattening, milk processing, and expansion of irrigation schemes.

NAP-ETH (2019) also highlighted the importance of sustainable agricultural production to ensure food security through promoting and adopting climate smart agriculture. Accordingly, specific activities such as inclusive extension system, crop and livestock husbandry, agro-forestry, introduction and promotion of heat resistant and drought tolerant varieties, application of organic manure and residues; crop rotation; crop disease and pest management; use of improved storage facility, drought and disease resistant livestock varsity, improving access to veterinary services and vaccines; use of shading and cooling facilities for poultry farming; and promoting better feeding systems have been emphasized by the government.

An attempt has also been made to strengthen sectors and institutions mainstream and implement climate change adaptation and mitigation measures. Accordingly, the ministry of Agriculture coordinates and oversees the implementation of the ministry's climate resilient strategy (CRGE) and ensures the mainstreaming of climate change adaptation into regular and flagship projects and program planned activities either under sector responsibilities or through international non state actors. Stakeholders such as Farm Africa, FAO, Gesellschaft fur Technische Zusammenarbeit (GTZ), Netherland Development Organization (SNV), United Nation Development Program (UNDP), United Nation Environmental Program (UNEP), World Food Program (WFP), etc.) have been supporting the implementation of planned activities in GTP-II.

The Agricultural Growth Program (AGP), primary objective is to increase agricultural productivity and market access for key crops and livestock products. AGP-I worked with 1.9 million households in 93 woredas of the four major regions in Ethiopia. AGP-II which started in 2018 had been implemented in 157 woredas (including the 93 from AGP-I) in eight regions. AGP was targeted at enhancing agricultural productivity and the increasing availability of improved technologies. It works on accelerating the introduction of technologies (crops, livestock, NRM, agricultural mechanization etc.), and adoption of technologies from elsewhere (within or outside the country) and development of demand driven agricultural technologies tailored to specific agro-ecologies and socio-economic conditions of the farming community.

The Ethiopian government has identified small scale irrigation as a feasible climate change adaptation strategy. Small scale irrigation could improve smallholders' adaptive capacity through multiple harvesting seasons and hence, surplus production of food items and high value crops for market. Though Ethiopia has high irrigation potential, so far only 2 million hectares (about 16 % of cultivated land area) is used for irrigation. Small scale irrigation is also one of the main components in the Green Climate Fund (GCF) project in Ethiopia.

The NPC is currently preparing Ethiopian 10 year's perspective plan as well as GTP-III, which has been implemented since July 2021. One of the major focus areas in the document is agriculture. This updated version focuses on free agriculture from rain dependence, on agricultural mechanization services, on contract farming, cluster approach and land consolidation, on livestock animal feed and animal health, on horticulture irrigation and urban farming, on private sector participation, on institutional implementation capacity, and on climate resilient sats in able agricultural development.

In Ethiopia, fishery exclusively comes from inland water bodies and is mainly both artisanal and subsistence in character. Regardless of the high potential of various species of fish; the sector is threatened by sedimentation, invasive species (water hyacinth), overexploitation, and expansion of investments around lakes. This is partly due to a lack of attention by the government and other stakeholders to the sector. Currently, the annual production of fish is estimated to be 31.5 thousand tons per year. Lake Tana leads the potential by an estimated 8,000-10,000 tons per year. Fish production from Lake Chamo is estimated at 4,500 tons per year. However, more than 60% of fish supplies are coming from Ethiopian main Rift Valley lakes. There is a need to assess the impact of climate change on fishing and design context-specific adaptation measures targeted to improve fishing production and its contribution to ensuring food security.

4.3.4. Water

4.3.4.1. Surface and underground Water Resource Overview

Ethiopia is bestowed with a larger volume of ground and surface water. The country's surface water covers 0.7% of the land mass and is estimated to be 124.4 billion cubic meters (BCM). Not surprisingly, Ethiopia has the reputation of being "water tower of North-Eastern Africa". Ethiopia has groundwater potential ranging from 2.5 to 47 billion cubic meters. The water resource particularly groundwater of the country is not yet well exploited.

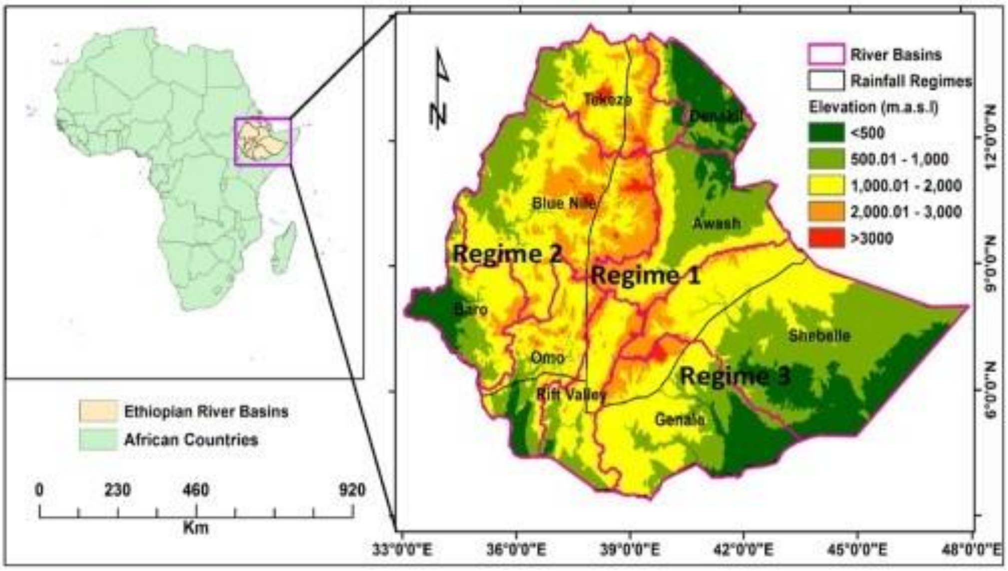


Figure 116 Ethiopians River Basins

Ethiopia has 12 river basins; however, the major river basins are nine such as Awash, Blue Nile, Baro, Danakil basin, Genale, Omo, Rift valley, Shebelle, and Tekeze having different climate, topography, vegetation and rainfall distribution. According to the Ministry of Water Resources (MoWR) of Ethiopia, the total mean annual flow from all these river basins is estimated to be 122 billion m3 (MoWR 1999). River flow and volume throughout Ethiopia is highly seasonal, with far-reaching implications for water accessibility, ecosystems, drought, and flooding.

There are three major rainfall regimes identified by the National Meteorological Agency (NMA) of Ethiopia (NMA 1996). As shown in Figure 120 Regime 1 encompasses the eastern and central parts of the country, and it has bimodal rainfall patterns (two rainy periods)(Lemma et al. 2017; 2019); February to May (Belg or smaller rainy season) and from June to September (Kiremt or main rainy season). Regime 2 is characterized by a long unimodal rainfall pattern from February to November (Lemma et al. 2017, 2019) and it encompasses the western parts of the country. Regime 3 comprises the southeast and southern parts of the country and is characterized by two separate rainy periods (bimodal rainfall patterns) from October to November (Short or smaller rainfall periods) and from February to May (long rainfall period).

4.3.4.2. Past Trends of Water Resources

Ethiopia is endowed with many small and large rivers. Majority Rivers originate from highland and except awash and Omo all cross the Ethiopian international boundaries.

Table 64 Major Ethiopians rivers

River	Catchment Area (km2)	Annual Volume BMC	Terminus/Mouth	Major tributaries

Abay(Blue Nile)	199,812	4.5	Mediterranean	Dabus, Dedessa, Fincha, Guder, Muger, Jema, Beshilo
Wabishebelle	202,697	3.4	Coast of Indian Ocean	RamisErer, DaketaFafan
GenaleDawa	171,042	6	Indian Ocean	Dawa, Weyb, Welmel, Mena
Awash	114,123	4.9	Inland (within Ethiopia)	Akaki, Kesem, Borkena, Mile
Tekeze	87,733	8.2	Mediterranean	Goang, Angereb
Gibe (Omo)	79,000	16.6	Lake Turkana	Gojeb
BaroAkobo	75,912	23.23	Mediterranean	Akobo

Source: Compiled from different basin development master plans

Due to highly elevated outward inclination and rugged landmass, spatial and seasonal varied climatic conditions, Ethiopian rivers have the following characteristics. 1) all major rivers originate from the highlands, 2) except Awash and Omo all majority rivers are international, 3) erratic and seasonal rainfall rivers are characterized by extreme seasonal fluctuation. In the wet season, runoff is higher and rivers are full bursting their banks, destroying small bridges, damage roads, crops, and flooding lowlands and grazing lands; during the dry seasons they became mere trickles of water or even dry up, 4) due to rugged feature rivers form rapids and waterfalls along their course.

Table 65 Area and annual runoff by river basin

Area1 (ha)			**As% of total area**	**Annual runoff**	**As % of total runoff**
			(%)	**(km3/yr)**	**(%)**
NileBasin		**36881200**	**32.4**	**84.55**	**69. 0**
	Abbay (BlueNile)	19981200	17.6	52.60	42. 9
	Baro-Akobo	7410000	6.5	23.60	19. 3
	Setit-Tekeze/Atba r a	8900000	7.8	7.6 3	6.2
	Mereb	590000	0.5	0.7 2	0.6

RiftValley		**31764000**	**27.9**	**29.02**	**23.7**
	Awash	11270000	9.9	4.60	3.7
	Denakil	7400000	6.5	0.86	0.7
	Omo-Gibe	7820000	6.9	17.96	14.7
	CentralLake	5274000	4.6	5.60	4.6
Shebelli-Juba		**37126400**	**32.7**	**8.95**	**7.3**
	Wabi-Shebelle	20021400	17.6	3.15	2.6
	Genale-Dawa	17105000	15.1	5.80	4.7
NorthEastCoast		**7930000**	**7.0**	**0.00**	**0.0**
	Ogaden	7710000	6.8	0.00	0.0
	GulfofAden	220000	0.2	0.00	0.0
Total		**113701600**	**100.0**	**122.52**	**100.0**

The areas are estimated and the total area is slightly different from the total area of the country, which is 110 430 000 ha. This last figure should be considered as being the correct one nationally Ethiopia is rich in lakes formed due to the tectonic process that took place during the Quaternary period. Except few, the majority of Ethiopian lakes are located within the Rift Valley System. The total area covered by lakes including wetlands, saline and crater lakes is estimated 7 000 km2. Wetlands serve as a source of water for rivers, flood retention and groundwater recharge. Wetlands are rich in biodiversity, sequester carbon and provide ecological and socio-economic benefits. In Ethiopia wetlands management has been given less attention and hence, the ecosystem is remarkably shrinking.

Lake Tana, the largest lake in Ethiopia has a shallow depth in the highlands. The Lake Tana depression is believed to be formed following slower sinking and reservoir by lava flow between Gojjam and Gonder massifs. Ethiopia is also gifted with crater lakes. These include the lakes at and around Bishoftu, Wonchi (near Ambo), Hayk (near Dessie) and the Crater Lake on top of Mount Zikwala. Lake Ashenge in Tigray is formed on a tectonic basin. Other types of lakes in Ethiopia are man-made created from hydroelectric power generation dams. Clusters of lakes are lined up within the Ethiopian Rift Valley. Lake Abaya is the largest of all the lakes in the system. The southern tip of the Rift Valley forms the marshy land called the Chew Bahir which is drained by Segan and Woito. Shalla and Ziway are the shallowest and the deepest lakes in the central Ethiopian Rift respectively (Table 4). The lake being created on the Ethiospian Grand Renaissance Dam will be the biggest lake in Ethiopia with considerable potential for fishing and irrigation development.

Table 66 Area and depth of some of Ethiopian Lakes

Lake	Area(km2)	Max. Depth(m)	Lake	Area(km2)	Max. Depth(m)
Tana	3600	9	Abijata	205	14
Abaya	1162	13.1	Awassa	129	10
Cham o	551	13	Asheng e	20	25
Ziway	442	8.95	Hayk	5	23
Shala	409	266*	Beseka	48.5	11
Koka	205	9			

Source: Compiled from different sources

4.3.5.Historical Drought in Ethiopia

Drought is one of the major hydro-meteorological hazards affecting particularly water, agriculture, and agriculture. The assessment of drought (1982-2016) in Awash, Blue Nile, Baro, Danakil, Omo, and Tekeze using SPI basins has been affected by meteorological drought. Accordingly, 1984, 1992, 2003, 2009, 2011, 2012, and 2015 were drought years (Lemma et al., 2022). The time series plots of SPI values show that most of the drought events in the above river basins occurred during their corresponding main rainy and smaller rainy seasons. Detailed Spatio-temporal investigations of the two worst drought years (1984 and 2011) and one drought-free year (2007) show that both the EDI and SPI could enable to identify the drought and drought-free areas correctly when compared with the available recorded historical droughts (RHD) across each river basin. The year 2007 was identified as a drought-free year except in some pocket areas (such as Awash, Danakil, and Tekeze) which showed mild drought, particularly during the smaller rainfall season. Similarly, the temporal trends of SPI identified drought show that the frequency and severity of drought were higher during the 1980s and 2000s than the 1990s (Lemma et al., 2022). SPI identified that some of the basins such as Awash, Tekeze, and Danakil river basins are frequently drought-affected areas of the country.

Table 67 Recorded historical drought in Ethiopia

Starting month/y r	Ending month/y r	Droughtaffectedareasof Ethiopia	River basins	No of affected peoples
05/1983	12/1984	Wollo, Gondar, Gore, Tigray, Shoa, Hararge, Sidamo	All river basins	7,750,000
06/1987	12/1987	Ogaden, Eritrea, Tigray, Wollo, Shawa, Gama, Gofa, Sidamo, Gondar, Bale	Danakil, Tekeze, Blue nile, Awash, Rift valley, Genale and Shabele	7,000,000
10/1989	12/1992	Northern Ethiopia, Eritrea, Tigray, Wollo, Gondar, Hararge	Tekeze, Blue nile Awash, Danakil, Omo and Baro river basins	6,500,000
02/1997	12/1997	Borana, Bale, South omo, Somali state	Rift valley, Genale and Shabele	N/A
09/1999	12/2000	Oromia, Amhara, Tigray, Benishangul gumuz, Gambela, SNNPR, Somali provinces	All river basins	4,900,000
01/2003	12/2004	Tigray, Oromia, Amhara, Somali, Afar provinces	All river basins	12,600,00 0
11/2005	12/2006	Afden, liben district (Somali provinces), Gode Zone (shabele district, Somali provinces), Borena	Rift valley, Genale and Shabele	N/A
05/2008	12/2008	Oromia, Somali, Amhara, Afar, Tigray, SNNPRprovinces	Rift valley, Genale and Shabele	6,400,000
01/2009	12/2009	Afar, part of Amhara, part of SNNP, Gambella province, Oromia, Somali, Tigray	Tekeze, Blue nile, Awash, Danakil, Omo, Genale, and shebele	6,200,000
01/2010	10/2010	Afar, part of Tigray, part of Amhara, part of SNNP, Gambela provinces and part of Oromia	Tekeze, Blue nile, Awash, Danakil and Omo river basins	N/A
01/2011	12/2011	Somali, Oromia, Afar, Tigray, Amhara provinces	All river basins	4,805,679
01/2012	01/2012	Somali, Oromia, Afar, Tigray, Amhara provinces	All river basins	1,000,000
09/2015	01/2016	Somali, Afar provinces	Rift valley, Genale and Shabele	10,200,00 0

(source: EM-DAT: www.emdat.be 2017)

4.3.6.Projected Climate Change and Associated Impacts on Water Resources

Evidence confirmed that freshwater resources are vulnerable to climate change with varying degrees of consequences on human settlements and ecosystems (Bates, et al., 2008). In Ethiopia, a decreasing trend of runoff and flow has been observed in recent years due to land degradation, climate change and population pressure. Water shortage was particularly severe in the lowlands than the highs. Ponds are drying up quickly after the end of the rains during the dry season due to increased evaporation resulting from increased temperature (Woldeamlak et al., 2015; Zelalem et al., 2009).

In Ethiopia, climate change has the potential to negatively impact the water availability, stability, access, utilization, and demand. Climate change and extremes induced, river flow and runoff of rivers and lakes are likely to decrease in the future and be insufficient to meet future demands for water of the ever-increasing population in the country. Climate fluctuations also affect the use of agricultural land associated with irrigation; complicate the design, operation, and management of water-use systems. This in turn has the potential to disrupt livelihoods, exacerbate poverty, food insecurity, and the marginalization of the poor and escalate inequality. Many concerns and issues surrounding water resources are increasingly linked to climate change. Given the economic role of the water resources, climate risk will be too costly to be tolerated and urgent measures must be taken to mitigate the impacts adopting feasible strategies.

The Blue Nile (Abay) river basin is one of the areas of the country most sensitive to climate change (Conway, 2005; Kim and Kalurachchi, 2009; Beyene *et al*., 2010). Over the next decades, it is expected to experience significant warming and changes to the temporal and spatial patterns of precipitation (Conway and Hulme, 1996; Yates and Strzepek, 1998; Conway, 2005; Kim *et al.*, 2008; Elshamy *et al.*, 2009; Kim and Kalurachchi, 2009; Beyene et al., 2010; Girma, 2012; Cherie, 2013). The Basin's vulnerability to the impacts of climate change is aggravated by land degradation, the increasing water demand and ineffective watershed management (McCartney and Girma, 2012; Di Baldassarre et al., 2011; Bates *et al*., 2008; ENTRO, 2006). Under the current climate trend, the water resource of the Blue Nile Basin, which supports millions of people in Ethiopia, Sudan and Egypt, will be remarkably affected by climate change. However, the basin runoff is estimated to increase from 3% for EC-EARTH driven RCM run by the near-term up to 14.6% for CNRM- CM5 driven run by the end of the 21st century compared to the 1981-2010 baseline period (Mengistu et al., 2020).

4.3.7.Adaptation Strategies in Water Resources

Though Ethiopia is generously endowed with water resources, its distribution is uneven both in space and time. Unmitigated hydrological variability is estimated to cost the country roughly one third of its growth potential (World Bank, 2006). Despite this, Ethiopia's investments on mitigation of these impacts and to harness its considerable water assets for overall progress has been very limited (World Bank, 2006). The 2010 GTP II planned to develop water resources to support 'green growth' for poverty reduction as the country strives to achieve a lower middle-income economy by 2025. The Ministry of Water and Energy (MoWE) is mandated to improve the management systems for water and sanitation facilities. Under its climate resilient strategy for water, the Ministry of Water, Irrigation and Energy (MoWIE) has identified two strategic priorities. Strategic priority 1) is to accelerate universal access to WASH (that prioritizes delivering OWNP by focusing on the most vulnerable). It strategies to reduce susceptibility to climate change through shifting people from using surface water sources to a more resilient groundwater sources. Strategic priority 2) aims to enhance climate resilience of self-supply. This strategic priority considers self-supply as the main element of OWNP though this could be susceptible to climate change impacts, because the typical technology choices are extremely exposed to rainfall variability. It considers adopting the most appropriate technology for the self-supply component, however, there are limited options and hence propose additional approaches to complement self-supply. It assumes that improved water sources are more resilient to climate change than unimproved sources. This is generally true because most improved sources are buffered from rainfall through groundwater (though springs and surface water sources remain exposed). The programme plans to integrate CRGE into the MoWIE, by instituting structures at federal level. It planned to set up monthly ministerial level meetings to review overall progress and strategic directions. It has also planned to establish four working groups (electric power, access to energy, water for growth, access to WASH) responsible to monitor and coordinate the delivery of sub-sector activities.

In 2019 Ethiopia developed its National Adaptation Plan that builds on the ongoing efforts to tackle the impacts of climate change. The goal is to reduce susceptibility to the effects of climate change through strengthening adaptive capacity and resilience. The plan aims to holistically reinforce integration of climate change adaptation in Ethiopia's long- term development plan, supported by effective institutions and governance structures, finance for implementation and capacity building and strengthened systems for disaster risk management and integration among different sectors. This adaptation plan is guided by the principles of participation, coherent interventions, stakeholder empowerment, gender sensitivity, equitable implementation and partnership. It focuses on the most vulnerable sectors, including forestry, agriculture, water, health, transport, power, and urban. It has identified 18 adaptation options, 3 of which are related to water (improving access to water supply; strengthening sustainable natural resources management through safeguarding landscape and watershed; improving soil and water harvesting as well as water retention mechanisms).

Today, Ethiopia has prepared a new strategy titled "Ethiopia 2030: The Pathway to Prosperity Ten Years Perspective Development Plan (2021 – 2030)" which has been implemented since July 2021. One of the strategic plans in the document is on building a climate resilient green economy. This updated version recognizes the impact of climate change on almost all sectors of the economy. It discusses that the effect of water scarcity and drought on food security may further exacerbate conflict over scarce resources. The effect of heavy rains, flooding and soil erosion on infrastructure are discussed in terms of how the poor and vulnerable groups are impacted. Drought incidence and reduced rainfall are not only impacting WASH infrastructures but also affecting food security, livestock and human health. The document describes the link between environmental degradation and water resources. These all signify the importance of sustainable adaptation and resilience interventions. The two strategic adaptation actions for water are improving resilience of water sources and improving access to potable water.

4.4. Human Health

The health impacts of climate change are manifested through morbidity and mortality caused by extreme temperature. Some impacts of climate change include increases in vector-borne diseases (malaria and bilharzias), communicable disease (Meningitis and Measles) and weather condition-related diseases (diarrhea and cholera). Climate change also undermines air quality while triggering mortality due to floods and storms, and malnutrition poor water supply (CRGE, 2012).

4.4.1.Vector-borne Diseases

According to the World Health Organization (WHO), 68% of Ethiopians live in areas at risk of malaria (WHO, 2010). Changes in climate are also likely to lengthen the transmission period of major vector borne diseases and alter their geographic range. Climate change is projected to expand the encroachment of malaria from lower altitudes in Somalia and Afar to higher altitudes in the Tigray and the Amhara regions of Ethiopia (NMA, 2007). Tanser estimated a 5–7% potential altitudinal increase in malaria distribution. Climate change-induced malaria has also been reported in the Afar region and in South Omo. In both places the rate of flooding has increased, and a large area has come under permanent flooding (Simane et al. 2017; Team and Hassen 2016; Dasgupta 2018). In addition, extreme rainfalls resulted in floods and post-flood stagnant waters which is a major factor that facilitates the spread of vector-borne diseases by creating breeding sites of mosquito larvae (Campbell et al. 2015; Wakuma Abaya et al. 2009).

4.4.2.Water-borne Diseases

The prevalence of diarrhea varies seasonally. An epidemic of cholera occurred following extreme floods in 2006, and led to widespread illness and loss of life (EDHS, 2011; UNDP, 2007). Outbreaks of acute watery diarrhea have occurred in different parts of Ethiopia since 2006 which led to the morbidity of thousands and the mortality of hundreds of people. Ethiopia already experiences a high flood risk. During the 2020 rainy season, numerous rivers had over flooded and affected more than a million people while displacing 292,863 people (Government of Ethiopia and OCHA 2020).

4.4.3.Zoonotic Diseases

Ethiopia was identified as a “hotspot” for zoonotic disease events. The country ranked number one hotspot for leptospirosis, the fourth largest hotspot for Q fever and Trypanosomosis, and the tenth for tuberculosis. Much of the burden of zoonosis (68%) is distributed among only 13 countries. Ethiopia has the 4th highest burdened country by zoonosis (Grace D., 2018). These data indicate an already existing burden of zoonotic disease in the country. The burden has the potential of being exacerbated by the effects of climate change. Researchers have identified an association between outbreaks of leptospirosis and extreme rainfall and flooding in a wide range of countries with different ecologies (Lau CL. et al., 2010).

4.4.4.Communicable diseases

Communicable disease outbreaks are primarily caused by displacement, including cross-border displacement. In Ethiopia, many communities are displaced due to the double burden of extreme weather events and conflict. As a result, outbreaks of communicable diseases are an urgent concern, particularly as they hamper the efficiency of the country’s public health infrastructure (Team and Hassen 2016; Irish Aid 2018). One of the communicable diseases in Ethiopia is Meningitis. In Ethiopia, since the first reported outbreaks of meningitis in 1901, there have been repeated occurrences in 1935, 1940s, 1950s, 1964 and 1977. This was followed by the largest epidemics in 1981 and 1989. Each occurrence affected almost 50,000 people (Habte-Gabr E. et al., 2010). The Southern Nations, Nationalities, and Peoples Region (SNNPR) and the Oromiya Region have been most severely affected in the past. The Amhara, Gambella, and Tigray regions also experienced significant impacts (Nzuma et al., 2010).

4.4.5. Nutrition-related Impacts

Reports on vulnerability mapping confirmed that Ethiopia is highly vulnerable to climate change and is the least capable to respond (McSweeney et al., 2008). The same study argues that climate change will be a major challenge to the country's efforts towards achieving food security and environmental sustainability. The impact of food insecurity and malnutrition is more severe on poor households that have no financial capacity to modify their herd composition (Riché et al., 2009). In Afar, food insecurity, malnutrition, and poor child growth and development are among the indirect impacts of climate change. Hagoset al., (2014) concluded that rainfall and temperature are partly responsible for problems of child stunting and underweight.

4.4.6. Impact of Climate Change on the Health sector in the Future

Ethiopia is expected to be severely affected by climate sensitive diseases and insects. The current and expected climate change and extremes particularly rising temperatures, erratic rainfall behavior, floods, and droughts could increase geographic scope, severity and prevalence of diseases (EPA, 2015). For instance, flood could facilitate the spread of waterborne diseases like diarrhea. Additionally, more than 70,000 deaths annually are tied to indoor and outdoor air pollutants. The link between drought and health is a major concern and the World Health Organization suggests that children born during a drought are 36% more vulnerable to diseases and malnourishment. Diarrheal deaths attributable to climate change in children under 15 years old is projected to reach 9.6% of the more than 42,000 diarrheal deaths projected by the 2050s. Although diarrheal deaths are projected to decline to about 15,500 by the 2070s the proportion of deaths attributable to climate change is projected to rise to approximately 14.1% (WHO, 2015).

Ethiopian huge livestock potential is partly undermined by the direct and indirect adverse impact of climate change and extremes (Gashaw et al., 2014). The impact of climate change on livestock health is far reaching and remarkably affecting individual households and the national economy ((Bernabucci, 2019). For example the frequent provenance of livestock diseases such as anthrax, blackleg, lumpy skin disease (LSD), ticks, and biting flies undermine livestock production and productivity and hence, the sector performance and contribution to individual household livelihood and national economy (Welay et al., 2018; Aklilu et al., 2013; Zelalem et al., 2009).

Lumpy Skin Disease(LSD): is an endemic climate change sensitive viral cattle disease affecting the sector in Ethiopia. The herd-level prevalence of LSD has been reported to be 44% (38-50%), with the mid-highlands having the highest prevalence (64%), followed by the lowlands (50%). Infected herds have a prevalence of 27% (22-32%), with 31% in the mid-highlands, 24% in the highlands, and 23% in the lowlands (Gari et al., 2012). According to Molla et al. (2017), morbidity was significantly higher in the intensive (17.5%) system than in the crop-livestock (10.1%) system. The intensive (4.0%) system had significantly higher mortality than the crop-livestock (0.7%) system. The impact of the disease could be controlled by vaccinating all animals over 6 months with either sheep pox or Lumpy Skin pox, but care must be taken not to introduce sheep pox into new areas. The disease is widespread in the country, and a vaccine is in use.

Foot and Mouth Disease (FMD): is endemic, with outbreaks occurring throughout the country. Seroprevalences of FMD in cattle range from 9% to 26% at the animal level and up to 48% at the herd level, on the other hand, the seroprevalence of FMD ranges from 5.6% to 42.7% in cattle. Serotypes O, A, and SAT2 were identified in Ethiopia between 2008 and 2019 and linked to two niches of FMD virus circulation in East Africa: one spanning thenorthern areas and including Ethiopia, Eritrea, Somalia, Sudan, and Southern Sudan, and the second covering Kenya, Tanzania, and Uganda in the south. (Gizaw and colleagues, 2020)

Contagious Bovine Pleuropneumonia (CBPP): is an endemic bacterial disease of cattle in Ethiopia, with seroprevalence ranging from 0.4 to 96% reported from various export quarantine centers and production areas. The reported seroprevalence is significantly associated with the country's various agro-ecologies, with the lowest reported for the lowlands, where 40% of the livestock population is kept (Abdela and Yune, 2017). The CBPP case fatality rate is estimated to be 16%. (Gulima, 2011).

Brucellosis: The bacterial genus Brucella causes Brucellosis, a zoonotic infection. Ingestion of infected food products, direct contact with an infected animal, or inhalation of aerosols are all ways for bacteria to spread from animals to humans. The disease has been known by several names over the years, including Mediterranean fever, Malta fever, gastric remittent fever, and undulant fever. Although humans are unintentional hosts, brucellosis remains a major public health concern worldwide and is the most common zoonotic infection. A high seroprevalence of 8% on average (4.0- 12.0%) in Southern Ethiopia, followed by Northern Ethiopia at 3% on average (1.0- 7.0%), and Central Ethiopia at 1% (0.0- 3.0%) and Eastern Ethiopia at 1% on average (1.0- 3.0%) (Tesfaye et al.,2021).

Contagious Caprine Pleuropneumonia: is a contagious disease caused by Mycoplasma capricolum subspecies capripneumoniae, which causes severe fibrinous pleuropneumonia in goats with respiratory distress, coughing, nasal discharge, and a high mortality rate. According to Asmare et al. (2016)'s meta-analysis of CCPP in Ethiopia, the pooled prevalence estimate was 25.7% (20.9%-31.0%). The prevalence for samples collected at the abattoir was 39.2%, while it was 22.4% for samples collected in the field.

Bovine Tuberculosis (BTB): is endemic in Ethiopia, with low prevalence in the extensive system ranging from 0.3% to 5.5% at the animal level (Tschopp et al., 2013) and high prevalence in urban and peri-urban dairy farms55% at the herd level and 32.3% at the animal level (Tschopp et al., 2013) . BTB was found in 0.83-5.2% of cattle slaughtered in abattoirs (Mengistu & Enquselassie, 2014), with the carcasses of 0.024-0.03% of cattle slaughtered in some abattoirs being completely condemned (Mummed & Webb, 2015).

Anthrax: Anthrax is a disease caused by Bacillus anthracis that causes sudden death with black tar-like exudates from natural orifices. Muscle tremors, mucosal congestion, and fever may precede collapse and terminal convulsions, which are followed by a dark bloody discharge after a 1-2 week incubation period. In less severe cases, listlessness, mucosal membrane hemorrhage, abortion, and swelling of the perineum, throat, and abdomen can last for 2 days. The sudden death of animals in the vicinity of known anthrax outbreaks raises the possibility of anthrax. The soil around an infected carcass becomes heavily infected with spores, which can survive for 20 years and be re-infected.

Although antibiotics are effective in the treatment of anthrax, the disease's usually rapid progression limits their effectiveness. When confirmed, strict regulations call for burying carcasses at 2 meters or completely burning the area and quarantining it for 6 months. Cattle vaccination in known outbreak areas is recommended for three years in a row.

Blackleg: Blackleg is an infectious but non-contagious disease caused by Clostridium chauvoei that affects young cattle and occasionally sheep/goats. The organism is common in soil where spores have been concentrated due to continuous grazing. The spores can be found in the liver and spleen of normal healthy animals, but they enter the alimentary tract through the mucosa membrane after ingestion. Spores can enter sheep and goats through wounds, including the reproductive tract after birth. The limb becomes cold, painless, and dark in color after a high fever, depression, anorexia, and lameness in an upper limb, with gas formation in the interior. Toxaemia kills within 2-3 days of developing a fever. In sheep and goats, the dark lesion usually appears at the site of the wound and organism entry. Antibiotics must be administered as soon as gas formation begins. Burning carcasses is an effective method of control. Vaccinating young stock is both inexpensive and effective. Before lambing, castration, or tail docking, sheep and goats should be vaccinated.

Pastuerellosis: Outbreaks occur during times of environmental stress, resulting in 50% to 100% morbidity and mortality. Pasteurellamultocida survives in infected animals' tonsils and nasal mucus tissues and is spread through ingestion or inhalation of contaminated forage. Death occurs within 24 hours of fever, profuse salivation, and depression. Antibiotic treatment is effective, as is vaccination, even in the face of an outbreak. These two mycoplasmic bacteria cause lungs and pleura lesions in cattle and goats, resulting in significant economic losses. Infected animals may take 3-6 weeks to develop symptoms such as fever, loss of appetite, coughing, arched back, and lowered head. The breathing is shallow, rapid, and labored. Death can occur within 1-3 weeks of onset of symptoms, or in less severe cases, coughing and weight loss can last up to 7 weeks. Mortality is usually 50%, with half of those who survive carrying the disease "encapsulated" in lung tissue and transmitting it to other herds for up to 3 years. Because the disease spreads via discharged nasal droplets, it is more likely to occur when cattle are confined.

Trypanosomiasis: also known as Tryps (human sleeping sickness). It is a parasitic disease caused by flagellate protozoa from the genus Trypanosoma that live in blood plasma and other body tissues and fluids. Trypanosomiasis was found in 9.61% of people in southwestern Ethiopia. These parasites are found in a variety of animals, but they appear to be pathogenic only to mammals, including humans. In Ethiopia, it is endemic, particularly in the southwest, west, and northwest. Trypanosomiasis evansi affects camels, with prevalence ranging from 2% to 10.9% in Afar and southern Oromia (Fikru et al., 2015).

The disease is always present, depending on the fly population, and has resulted in a loss of 500 million birr in five zones of western Oromia.

Pestedes Petits Ruminants:PestedesPetitsRuminants(PPR)isanendemicviraldiseaseof sheep and goats in Ethiopia. The prevalence of PPR in sheep and goats was 6.4% in a countrywide study that included 43 districts, with the lowest prevalence (1.7%) in Oromia region and the highest (21.3%) in Somali region. Gariet al. (2017) found 48.43% PPR seropositivity in the Oromia Region's East Shewa and Arsi Zones. Vaccination is an essential component of Ethiopia's efforts to eliminate the disease as part of the Global PPR Control and Eradication Strategy.

Pox: Sheep and goat pox are viral infections that cause fever, generalized papules or nodules, vesicles (rarely), internal lesions (especially in the lungs), and death. Both diseases are caused by capripoxvirus strains that can infect sheep and goats. There is little research on the prevalence and trends of caprine and ovine pox in Ethiopia, but it is thought to be widespread. According to Fentie et al. (2017), seroprevalence in the Amhararegion ranged from 11.9% in North Gondar and West Gojjam zones to 20.9% in South Gondar. Females and young animals were more vulnerable than their male counterparts.

Endoparasites: **a**re parasites that live inside a host, typically in the gut, lungs, heart, and blood vessels. They are extremely common in all species throughout the country. Endoparasites pose a greater challenge in extensive production systems than in intensive systems (Emiru et al., 2013).

Ectoparasites: Ectoparasites are parasites that live on the host animal's skin or coat. In Ethiopia, national surveys on ectoparasites are lacking. Ectoparasite prevalence rates ranged from 15.4% to 40.2% in various parts of the country. The overall prevalence of ectoparasites in sheep was 48.1% in central Ethiopia (Kumsa et al., 2012). Ectoparasite control programs have been implemented in certain regions for several years; however, the prevalence does not appear to be decreasing Ectoparasites are a major source of skin rejection in tanning plants (Tolossa, 2014).

Infectious Bursal Disease: Infectious bursal disease (IBD), also known as Gumboro disease, is an immunosuppressive disease that affects young chickens. Infectious IBD is present in 77.48% of Ethiopian chickens. In the dry season, the prevalence was 91.9% in backyard chickens sampled at markets in central Ethiopia, and 96.3% in the wet season (Chaka et al., 2012). A six-month follow-up study in two districts in northwest Ethiopia revealed cumulative incidence rates of 17.40% and 38.39%, respectively, and case fatality rates of 77.73% and 98.56% in village chickens of Farta and Bahir Dar Zuriya districts. A mortality rate of 49.89% was reported in a commercial poultry farm outbreak in Bishoftu, central Ethiopia (Zeleke et al., 2005).

4.4.7.Adaptation Measures in the Health Sector

Ethiopia has a Health National Adaptation Plan to Climate change. The plan was released in 2019. The plan recognizes that drought, flooding and heat stress are exacerbated by climate change and variability. It has identified climate sensitive diseases, namely, waterborne, food borne and/or vector borne diseases. It explains the fact that local changes in temperature and rainfall alters distribution of certain water borne diseases and disease causing vectors. According to the plan, vector borne diseases (including malaria, dengue fever, yellow fever), water borne diseases (diarrhoea, scabies and/or AWD), respiratory tract infection (bronchitis, influenza), and heat stress are diseases sensitive to climate change. Water borne diseases are caused by poor personal hygiene and use of unsafe water.

The plan recognizes that unimproved sanitation facilities are susceptible to flooding because they have poor superstructure and are less mounted than walls that may not prevent the latrine from filling by rain and runoff water. Reports show that the majority of the household latrines, particularly in the rural areas are unimproved, and hence they are exposed to flooding during rainy seasons.

One strategy identified to integrate climate change adaptation to health programmes is maximizing the provision of climate information so as to forecast and prevent diseases sensitive to climate change. The other strategy is building and renovating WASH facilities that are resilient to climate change. Activities related to sanitation that was proposed to be integrated in the health sector structures from federal to grassroots level was to develop and adapt climate proof latrine design and technology guidelines and integrate this into existing OWNP. This was planned to be accompanied by training on the improved and climate resilient latrine design and technology options to be promoted through advocacy and awareness creation.

4.5. Forestry

4.5.1.Overview of Ethiopia's forest resource coverage, importance, and challenges

According to a recent assessment by the National Forest sector Development Programme NFSDP (2018), Ethiopian forest coverage is estimated to be around 17.35 million hectares of land, accounting for around 15.7% of the country's total area, with a vast expanse of degraded lands ideal for forest restoration. In comparison to 2015, the increment was by around 5 million hectares. This recent increase in forest canopy could be the consequence of the Ethiopian government's afforestation campaigns carried out annually under the program of Green Legacy.

From the country's total forest coverage, the major portion falls under FAO's "forest" classification which is defined as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use" (FAO, 2010), followed by dry land and woody vegetation. Despite the challenges facing the forest environment, the forest sector is critical to Ethiopia's economy, food security, income generation, and long-term livelihoods for millions of Ethiopians (REDD+, 2017). Although calculating the direct and indirect contribution of forests to Ethiopia's GDP has proven difficult, an official report from the ministry of finance and economic commission (MoFEC) (2016) shows that Ethiopia's forests generated economic benefits in the form of cash and in-kind worth 16.7 billion USD in FY 2012-13, or 12.9% of GDP measured value.

Ethiopian forest coverage is under immense pressure mainly from forest clearing for cropland expansion and domestic energy consumption. Of the total energy consumption in Ethiopia, about 94% is fulfilled from biomass (EPCC, 2015, CRGE, 2011). The forest ecosystem is being affected by habitat conversion, unsustainable biodiversity resource use, encroachment of invasive species, and replacement of natural forest by commercial tree species mainly Eucalypts (IBC, 2014). Climate change played a significant role in the loss of forests through forest fires as well as changing forest composition due to altitudinal shifts and soil organisms and nutrients deterioration. Unless action is taken to alter this typical destructive route, nine million hectares of land might be cleared between 2010 and 2030 (CRGE, 2011). Over the same period, annual fuel wood consumption will rise by 65%, resulting in the deforestation of more than 22 million tons of woody biomass. Deforestation would ultimately affect the effort made to adapt to climate change and the reduction of GHG emissions and GHG sequestration capacity.

4.5.2.Vulnerability Ethiopia's Forest Resource to Climate change

The projected rapid rise in temperature, combined with other stresses such as habitat destruction due to land-use change, could easily disrupt the connectedness of species, transforming existing communities and demonstrating the variable movement of species through ecosystems, potentially leading to numerous localized extinctions. This problem is strong observed in the Afroalpain and afromontan forest ecosystem in the highlands of Ethiopia located in the north and southeast (EPCC, 2015). The predicted rise in temperature in the Ethiopian highlands as a result of climate change is likely to have an impact on the distribution of endemic mountain species. As a result, the pronounced climate variations are likely to have a significant impact on the regional distribution of plant species and forest communities in Ethiopian forests. Consequently, if some plant species are unable to adapt to climate change, ecosystems may become more vulnerable to natural and anthropogenic disturbances, resulting in a loss of species diversity. The impact of climate change threats vary by region but are generally reflected in changes in growth rates, species composition and density, and ecosystem shifts (Aynekulu et al., 2019).

A loss in forest health and productivity has been attributed to climate change. Global warming-induced changes in hydrology, rainfall patterns, storm frequency and intensity, fires, pests, and diseases may have far-reaching implications on tree phenology, productivity, and regeneration (Eshetu, 2013). For instance, the occurrence and frequency of fires has increased in recent years in the Bale-eco region as the temperature has risen and anthropogenic intervention intensified (REDD+, 2017). In forest ecosystems, rising pest/disease incidences resulting from climate change have also an adverse impact on the forest ecosystem. High temperatures amid extreme drought circumstances caused considerable tree dieback in a dry Afromontane Forest (Ayinekulu et al., 2011).

4.5.3.Forest-Related Projects for Climate Change Adaptation

Ethiopia has been pursuing a green economic growth path to achieve middle-income status by 2030. Ethiopia's green economic development plan aimed to reduce GHG emissions from 400 Mt CO_2 equivalent under the current development path to 250 Mt CO_2 equivalent by 2030. Hence, in the forest sector protecting and re-establishing forests for their economic and ecosystem services, including carbon stocks, is one of the pillars of the country's green economic development path, which considers climate change adaptation mechanisms (CRGE, 2011). CRGE strategy encourages area closure through the rehabilitation of degraded pastureland and farmland, resulting in increased soil fertility and, as a result, increased carbon sequestration (above and below ground), as well as adapted climate change impacts such as flooding and water resource depletion.

Forest resources are critical in climate change adaptation because they help to mitigate the effects of climate change such as water depletion, soil nutrient restoration, and flooding (Nigussie et al., 2017; Huang et al., 2017). Consequently, protecting and re- establishing the forest ecosystem have been considered the major directions in climate change adaptation by Ethiopia, (CRGE, 2011). According to the CRGE strategy, reducing energy demand from biomass through the supply of alternative energy sources such as electricity, LPG, or biogas and disseminating energy-efficient stoves would increase forest cover. This will be accompanied with afforestation, sound forest management, and enclosure as pillars of climate change adaptation in the forestry sector. Further, restoring indigenous agroforestry practices, such as home gardening or coffee agroforestry, can be climate change adaptation mechanisms that contribute for carbon sequestration and mitigation of greenhouse gas (GHG) emissions (Kim et al., 2016; Mbow et al.,2014).

Various forestry and forest-related economic activities, particularly for women and indigenous peoples, could help them cope with climate change by giving alternative

income diversification opportunities. Non-timber products such as coffee harvesting, beekeeping, gum, and incense production, and spice production are examples of economic diversification activity. Carbon trading schemes, which are now in practice, have also provided local people with the potential to profit financially from the preservation of existing forests and reforestation. These practices will provide a chance for local communities to get financial benefits through carbon trading schemes that are currently being developed (Beyene et al., 2016; Hailemariam et al., 2015).

4.5.4. Legal and institutional frameworks climate change adaptation in forest resource

The Ethiopian flora is estimated at 6000 species of higher plants of which 10% are considered to be endemic of which woody plants constitute about 1000 species (IBC, 2012). Following this ample diversity, Ethiopia has worked to safeguard it in a variety of ways, including the establishment of protected areas and agencies responsible for forest protection and conservation. Exempting NGOs, currently, governmental agencies that are involved in forest-related issues are FDRE Environmental Protection Authority (EFA), Ethiopian environment and forest institute, Ethiopian forest research center, Ethiopian Biodiversity conservation, and Ethiopian wildlife conservation authority and their regional office throughout the country have direct involvement in forest ecosystem conservation. The protection of forests in Ethiopia is mainly led by the government, hence the largest portion of forest areas are under the protection of public administration. Some patches of the forest, however, are protected through joint management with the local community.

The first protected area was established in the 1960s, and since then several biodiversity conservation areas have been established (SDPASE- EWCA, 2015). Today about 73 protected areas fall under six management categories covering roughly about 14% established in Ethiopia. These include 27 national parks, 2 wildlife sanctuaries, 6 wildlife reserves, 25 controlled hunting areas, 5 biosphere reserves, and 8 community conservation areas5 (SDPASE- EWCA, 2015). In total, the protected area accounted for about 8.3% (9, 3182 km^2) of the total land mass of the country and represents all major ecosystems of thecountry.

The fauna species encompassed by the protected area network include 320 species of mammals (57 are endemic), 926 species of birds, (18 are endemic), 242 species of reptiles (15 are endemic), 73 species of amphibians (30 are endemic), 180 species of fish (41 are endemic), about 6500 species of vascular plants (700 are endemic) and 6862 species of insect have been recorded (Berehanu Beyene, 2016). However, some discrepancies in the number of the species exist. For instance, according to (IBC, 2009; USAID/Africa, 2008; Redeat Habteselassie, 2012) the Ethiopian wild fauna are comprised of 284 mammals (29 are endemic), 861 bird (18 are endemic), 201 reptiles (10 are endemic), 200 fish (40 are endemic), 63 amphibia (25 are endemic) and 1,225 arthropod (7 are endemic) and 324 butterflies.

Establishing protected areas has dual functions; it helps conserve the ecosystem and wild flora and fauna which in turn mitigate climate change effects through carbontrading and CO_2 sequestration. In this regard, the REDD+ Bale Eco-region REDD+ project being implemented in the Bale Mountain National Park to reduce CO_2 equivalent by 18 million $MtCO_2$ through financing for the conservation of the forest is a case in point. Besides contributing to climate change adaptation, protected areas generate an estimated 1.5 billion worth dollars per year from direct and indirect economic value for Ethiopia (IBC, 2014).

Table 68 GHG mitigation and adaptation projects in the forestry sector in Ethiopia

Project Name	Funder	Location	Estimated C emission reduction	Notes	Years
Bale Mountains Eco-region REDD+ Project	Norway through the World Bank	Bale Mountains, Oromia Region	18 million $MtCO_2$	The largest REDD+ pilot project in the country to date. The program was initiated by Farm Africa and SoS Sahel to organize PFM in the Bale eco- region and help local communities sustainably manage forests. The project covers about half a million ha and is intended to run for 20 years.	2013-2033

The Humbo Ethiopia Assisted Natural Regeneration Project	World Vision Ethiopia	Wolaita zone, SNNPR	880,295 $MtCO_2$	Afforestation and reforestation activities including regenerating native forests, reducing soil erosion, and establishing income streams for local communities among others. Focus on community involvement.	2007-2036
The Abo te Community-Managed Reforestation Project	World Vi sion Ethiopia	Oromia Ethiopia	2.67 million $MtCO_2$	Afforestation, reforestation, and revegetation activity implemented on existing communal forestlands and croplands. Uses the Climate Community and Biodiversity Standards.	2008-2038
Sustainable Land Managemen tProgram 2013-18	Inter. Develop. Assoc. and the Glo bal Environ. Facility	Nation-wide		Although not a carbon project, rehabilitation work in 45 critical watersheds in 6 regions has been undertaken.	2013-2018
The Sodo Community Managed Agroforestry & Forest ry Project	World Vision Ethiopia and World Vision Australia	Sodo Zuria, SNNPR	189,027 $MtCO_2$	Certified Emission Reduction purchase agreement (1 ton CO_2 = $9 USD)	2006-2041

(Source UNFCC: https://cdm.unfccc.int/)

4.6. Tourism

Tourism is a social, cultural, and economic activity that involves individuals traveling to countries or places outside of their normal environment for personal or professional reasons (Gretze et al., 2015). Ethiopia is the oldest and the second-most populous developing country in Sub-Saharan Africa that builds a tourist industry which contributes significantly to the country's social, cultural, and economic growth (WTO, 2008; Degarege, 2019). It has almost every type of top tourist attraction center, including historical sites, national parks with endemic wildlife, and cultural and religious festivals. The obelisks of Axum, the monolithic rock hewn churches of Lalibela, Gondar's castles, the Omo Valley, Hadar (where the skeleton of the hominid "Lucy" was discovered), Tiya's carved standing stones, the Semien National Park, and the walled city of Harar are all UNESCO world heritagesites.

Tourism contributes roughly 5.5% of Ethiopia's Gross Domestic Product and is rapidly increasing. The government is demonstrating its dedication and willingness to promote tourism. This provides both the theoretical framework and context for describing Ethiopia's tourism sector, as well as an illustration of the strategic options available to develop this sector and support the country's broader development needs. Development economics, tourism planning and tourism policy, and strategic destination development are among the theoretical constructs investigated. As a result, scenarios were constructed showing possible impacts and consequences of climate change on the international tourism system, providing valuable information for adaptation purposes, as well as planning adaptation actions, and minimizing impacts & vulnerabilities.

Ethiopia's tourism industry is in its early stages. Its current low level of development is often attributed to weak governance systems, lack of supportive policies, lack of trained manpower, finance, and knowledge and management capacity to promote divers tourist attraction sites and provide effective services and facilities. Ethiopia’s tourism has been more focused on the socio-cultural and historical aspects of the country’s development. As the world’s largest industry, tourism brings the tourist and service provider together and produces an experience for both. The number of tourist arrivals registered in Ethiopia each year that spends at least one night in the country but does not live there for more than 12 months has been increasing (Figure 121)

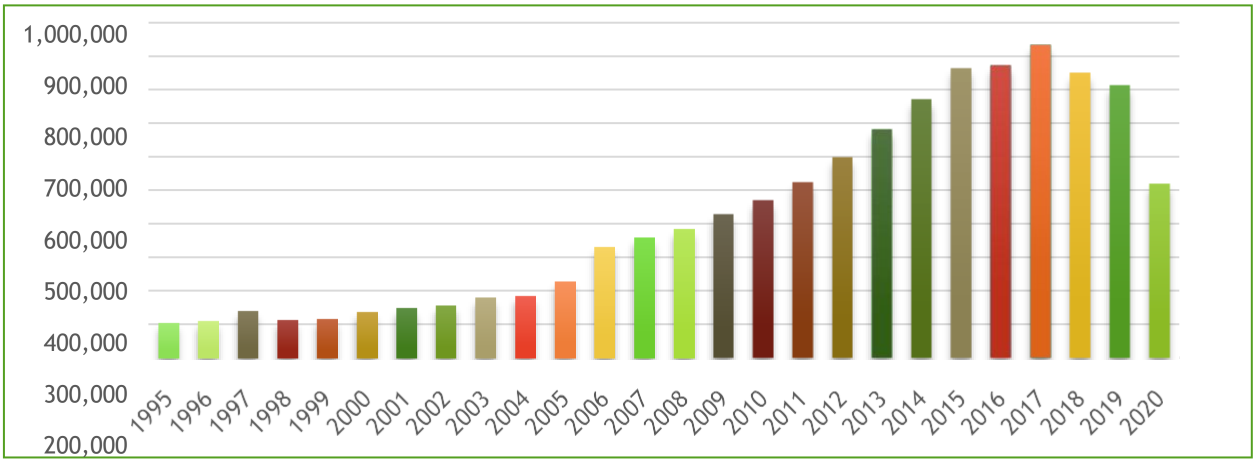


Figure 117 The number of tourist arrivals registered from 1995-2020

The number of tourists traveling across borders is expected to reach 1.8 billion a year by 2030, according to the latest UNWTO predictions. This will be alongside a further 15.6 billion domestic tourist arrivals. Such growth will bring many opportunities, including socioeconomic development and job creation. Tourism sales in Ethiopia in 1995 was around 177.00 million dollars which accounts 2.3% of the country's GDP. This equated to around 103,000 tourists at the time, or $1,718 USD per person. In Ethiopia, recently each visitor now spends an average of $4,405 USD on their vacation. Ethiopia’s Travel and Tourism economy grew by 48.6% in 2018 the largest of any country in the world according to the World Travel and Tourism Council’s annual review of the economic impact and social importance of the sector. In 2018, Travel and Tourism contributed $7.4 billion to the country's economy, an increase of $2.2 billion on 2017 (Asefa, 2020). However, due to COVID-19 and other human induced risks the tourism sector has been remarkably affected.

The existence of this potential can create a suitable condition for developing the tourism industry. Though the sector is still at its infant stage, Ethiopia is rising as a prominent tourist destination in the world. This Eastern Africa nation has over the last year taken a deliberate stride aimed at harnessing its tourism products, packaging them properly and displaying them to the local, regional and international markets (Ethiopian Tourism Commission, 2015.). In 2017, tourism contributed about 6.9% of the total employment (1.6 million jobs) in the country and 7.1% of Ethiopia's GDP (Merga, 2019). The World Travel and Tourism Council's annual research report on the economic impact of tourism in Ethiopia travel & tourism, 2015 offers some insight on the country's lagging nature. The increment of greenhouse gas emission from tourism-related transport is challenging the realization of the Paris Agreement which seeks to enhance the resourcefulness of tourism in Ethiopia (Friedlingstein et al., 2021; Scott et al., 2016).

4.6.1.Current and Future Impacts of Climate Change on Tourism

Climate change is already taking place now, thus past and present changes help to indicate possible future changes (Grimm et al., 2018 and IPCC, 2018). The tourism industry is among climate change sensitive sectors (IPCC, 2019; Daniel et al. 2015; Rayamajhi, 2012). The impact of climate change on tourism could manifest directly from the rise of temperature, erratic rainfall distribution, increasing the intensity and frequency of drought, flood and temperature extremes or indirectly due to maladaptation practices employed by individuals and communities to cope with the adverse impact of climate change. The direct and indirect adverse impact of climate change could affect the tourism industry profitability and sustainability. Therefore, appropriate response measures should be designed and implemented to conserve the natural tourist attraction centers and wildlife, and improve the services and facilities in a climate smart manner.

In general, climate change could cause basic infrastructures damage and service interruption, disappearance and reduction of biodiversity, migration of wildlife, hinder the movement of tourists and affect the livelihood of people who depend on the sector and the national economy in large. On the contrary the tourism industry contributes Greenhouse Gas (GHG) emissions, through emissions from transport, accommodation and activities (United Nations Environment Programme, 2008). The spatio-temporal climate variable trend and variability as well as climate extremes of Ethiopia confirms the tourism sector is vulnerable to climate change and requires adaptation and mitigation measures to properly address the problem.

4.6.2.Adaptation Strategies in the Tourism Sector

The World Travel and Tourism Council (WTTC) is at the forefront of the effort geared towards addressing the tourism industry's primary hurdles on climate. The WTTC has released a strategy in September 2019 to achieve carbon neutrality by 2050. The World

Tourism Organization (UNWTO) is taking the lead on tourism under the auspices of the United Nations. At COP25, a side event on tourism transformation for climate action emphasized the importance of adopting a low-carbon path, with awareness and optimization as crucial components (UNWTO, 2019). The UNFCCC's National Adaptation Program of Action (NAPA) is a system meant to assist Least Developed Countries (LDCs), such as Ethiopia, in identifying and communicating their priority adaptation needs to climate change to the UNFCCC's Conference of Parties (COP) and other concerned bodies. The goal of Ethiopia's NAPA document is to identify immediate and urgent adaptation efforts to address the existing and anticipated negative effects of climate change, especially extreme weather occurrences. It provides a flexible framework to manage the country's coordination and implementation of adaptation activities through a participatory approach, while also fostering synergies with other important environmental and related programs and projects. The mission of the Ethiopian Ministry of Culture and Tourism (2016) is to "study, preserve, develop, and promote the cultural wealth and national tourism attractions of Ethiopia's nations, nationalities, and people. It also outlinesitsgoalofmakingEthiopiaoneofAfrica'stopfivetouristdestinationsby2020.

Cognizant of the tourism potential and importance of the sector to the national economy; the first Ethiopia tourism development policy was launched in 2009. The new Ethiopian tourism policy designed to integrate the country's tourism with agricultural, industrial, and foreign policies and strategies was established in 2019. The new tourism policy considers the participation of stakeholders and capacity building to promote natural and manmade tourist sites, create employment opportunities and improve the sector contribution to the national economy and poverty reduction efforts. The tourism policy of Ethiopia is significant for the purpose of this study because it guides and shows the way for identification of tourism development challenges and opportunities in the country as shown in Table 74.

Table 69 Samples of strategic plans that may sustain the tourism sector

No	Activities	Potential adaptation option
1	Improving air quality	• Developing a federal strategy, standards and law to improve urban air quality • Developing a national strategy to enhance coping mechanisms regarding the adverse impacts of climate change • Launching environmentally sound investment and other programs that foster cleaner development mechanisms, including emissions trading
2	Environmental policy of Ethiopia: Natural resource & environment	• Establish environmental forums to promote education & communication (IEC) networking to introduce environmental protection, environmental health care, etc. • Awareness creation programs about the effects of GHGs emission, effects on climate change & natural environment • Natural resources conservation & development projects (tree planting, soil conservation, protection of water resources & introduce appropriate water harvesting techniques, etc) • Establish & build national capacity to undertake climate monitoring

		programs
3	Water resources policies & strategies:environment	• Conduct water resources assessment studies (inventory of water quality and quantity, surface and underground water in time and space to develop proper use of available waterresources • Introduce improved methods of water conservation, storage and rational use • Construction of small check dams and rainwater harvesting schemes to meet water supply for domestic and irrigation use • Undertake soil conservation measures that help to reduce soil erosion & siltation and also protect the pollution of water sources • Implement watershed management and water conservation programs & projects that promote local community participation • Introduce methods to tackle & prevent flood protection, disaster prevention actions; and maintenance of flood control structures • Manage and tackle droughts as well as the associated slow on-set diseases
4	Health policy	• Implement programs that help to prevent and control communicable diseases like malaria through community participation • Organize and implement community – based health education programs to create the awareness & develop the knowledge about personal hygiene & environmental health management • Develop & introduce surveillance system, introduce methods of health prevention & vector control for health workers and the community • Provide training programs to build the manpower capacity to improve the provision of health extension services at local level • Support health research & community health services through the supply of drags and help the development of • health facilities & infrastructure
5	Energy policy	• Initiate & develop projects that promote the use of alternative and or non-wood energy sources (e.g. bio-gas, fuel saving stoves,etc) • Increase awareness about the effect of pollution on the environment through IEC with focus on energy utilization and environmental education • Enforce laws & regulations to protect and prevent pollutions and ensure utilization of local factories that are environmentally friendly

This systematic review report described pertinent features of climate change and variability so that concerned actors can use it as a valuable input for adaptation purposes. Considering that different estimates are generated about the socio-economic and environmental impacts of climate change on different economic sectors, it is advisable to strictly plan based on sector specific application of scientific data. Governments and communities should seek to develop a normative framework that promotes energy efficiency, promotion of education, and awareness creation programs custom-made for the tourism industry.

4.7. Biodiversity

Ethiopia is one of the top 25 biodiversity-rich countries as it is home to two of the world's biodiversity hotspots namely the Eastern Afromontane and Horn of Africa hotspots (WCMC, 1994). This abundant biodiversity and ecosystem mirror the country’s immense altitudinal variations; Ethiopia’s altitude ranges from 116 meters below sea level in the Danakil Depression in the northeast to 4,620 meters above sea level on Mount Ras Dashen in the north (IBC, 2014). The altitudinal variation results in the great diversity of plant, animal, and microbial genetic resources, as well as multiple ecosystems. Ethiopia has 10 ecosystems, and 18 major and 49 minor agro-ecological zones (EPCC, 2015). Ethiopian ecosystems can be broadly classified as Afroalpine & sub-afroalpine, Wetlands, Dryland, Forest, and Agrobiodiversity ecosystems (EPCC, 2015).

These ecosystems contain biodiversity that is vital to the country and the world at large. The Afroalpine and sub afro alpine ecosystems located in the southeastern and northern Ethiopia, for example, are home to a variety of wild animals, including the endemic Walia Ibex, Mountain Nyala, Ethiopian Wolf, Gelada Baboon, Giant Mole Rat, Grass Rat, Klipspriger, Golden Jackal Caveat Cat, Caracal, Ratel, Rock Hyrax, Grey Duiker, Anubis Baboon, Porcupine and Abyssinian Hare. Blue Winged Goose, Wattled Ibis, Thick-billed Raven, White-collared Pigeon, and many other rare and uncommon birds can be found in this ecosystem (Tesfaye Awas et al., 2003; IBC, 2005).

The dryland ecosystem covers the larger portions of the Ethiopian landmass. The dryland ecosystem is sub-divided broadly as hyper-arid, arid, semi-arid, and dry sub-humid (Amanuel et al., 2019). The vast drylands in Ethiopia encompass diverse ecosystems such as grassland, woodlands, shrub lands, bush tickets, agro-ecosystems, forests, and aquatic ecosystems. The Rift Valley lakes and their associated wetlands are included in this ecosystem. This ecosystem is also home to avian and wild animals and is an important ecosystem mainly for the pastoralist community living in the north-eastern, eastern, and southeastern parts of the country.

Ethiopia is a center of agro-biodiversity and is one of the eight Vavilovian Centres of crop origin/domestication and diversity (EPCC, 2015). It is home to crops of global importance such as sorghum, millet, Arabica coffee, durum wheat, and teff (Fassil Kebebew, 2010). Ethiopia also contains significant gene pools of crop wild relatives for at least 120 different crop species, including grains, pulses, oil seeds, vegetables, tubers, fruits, spices, stimulants, fibers, dyes, and medicinal plants. Furthermore, several crops that were domesticated outside of East Africa have a high level of secondary diversification in Ethiopia, as evidenced by farmer wheat, barley, and pulse varieties. Agricultural activity employs more than 80% of Ethiopia's population and approximately 97% of total agricultural land is cultivated by smallholders who produce more than 97% of agricultural outputs (Wondimagegn et al., 2011). Considering this and that agriculture has been practiced in Ethiopia for millennia, the agrobiodiversity resources are quite striking. Overall, the country has a wealth of genetically diverse populations and species-rich agro-ecosystems that would contribute significantly to climate change adaptation. Similar to the crop diversity, the livestock diversity of Ethiopia is undisputable. According to CSA (2014) report, there are about 55 million cattle, 28 million goats, 27 million sheep,

1.1 million camels, 2 million horses, 7 million donkeys, and 51 million chickens. Except for chicken and cattle, where exotic and crossbred animals account for about 2.2% and 1.3% of the population, respectively, the remaining livestock population is almost entirely indigenous animals.

4.7.1.Impact of Climate Change on Ethiopian Biodiversity

Ethiopia has experienced climate change, with temperatures increasing at a rate of 0.2°C per decade over the last few decades (Elshamy et al. 2009) . Precipitation, on the other hand, has remained relatively stable over the last five decades, but it has high spatiotemporal variability (CRGE, 2011). Future projections indicated an increasing trend in temperature mainly in the late century and a decrease in precipitation in the summer and spring seasons. Recurrent drought and the starting and ending of precipitation variability will be also expected. These changes will impact biodiversity in different ways such as through increasing invasive species-area coverage and frequent forest fires (REDD+, 2017). Although there is a lack of quantified data to link climate change to biodiversity loss in Ethiopia, late rains and droughts have been observed to harm the gene pool of genetic resources, cause high disease prevalence such as Pasterolosis, and encourage invasive species such as Acacia drepanolobium to invade rangelands (Keller, 2009).

Ethiopia has a history of extreme weather variability, especially erratic rainfall that causes droughts and floods. Climate change is expected to increase the frequency of severe flooding, droughts, and extreme heat days which affects biodiversity by impacting ecosystem processes and functions; habitat degradation and loss; shifts in the geographic ranges of native plants and animals; changes in the timing of life-history events; invasive species and disease spread; declines in species, populations, and genetic resources; and extinction or loss of biodiversity resources will be expected. However, the impact of climate change on Ethiopian biodiversity may vary among ecosystems. The afroalpine and sub-afroalpine ecosystems are extremely fragile and threatened by extreme climatic conditions like cold temperatures, high radiation, and physical disturbances from wind and other factors because they are isolated from the surrounding ecosystem and are an island ecosystem high in the mountain (EPCC, 2015).

Ethiopia's numerous wetlands (streams, rivers, lakes, dams, ponds, swamps, marshes, etc.) supports wetland birds and fish diversity. However, wetlands and their diversity are under threat from climate change, anthropogenic, and ecological causes (Woldu, 2003). Numerous streams, rivers, ponds, and lakes have dried up as a result of extreme weather events and drought, which have caused a considerable drop in water level (volume and surface area). According to Dejen (2013), Wondie (2013), and Zegeye (2017), the effects have already been felt by Lakes Tana, Ziway, Langano, Abijata, and Chamo, while Lake Haramaya has dried up.

Low rates of forest species regeneration due to climate change have been observed in Ethiopia. For instance, Juniperus procera and Olea europaea subsp. cuspidata dieback in the Desa'a forest in Northern Ethiopia as a result of climate change were reported by Aynekulu et al. (2011). Species with limited geographical opportunities, restricted habitat requirements and/or small populations (for example, species restricted to Afroalpine ecosystems, such as Giant Lobelia, Walia Ibex, Ethiopian Wolf) are the most vulnerable (Zerga and Gebeyehu, 2016). Further, climate change enhances the spread and abundance of invasive alien species such as Parthenium hysterophorus and Prosopis juliflora endangering the country's biodiversity (Tadesse, 2001; Berhanu and Tesfaye, 2006; Zegeye, 2017; Sharma and Nigatu, 2013). According to the Environmental Protection Authority (EPA) reports from 2010 and 2011, the effects have been seen in the lowlands of the regional states of Afar, Somalia, and Oromia. The intensified expansion of invasive species witnessed in the farmlands and protected areas hampers both agro- biodiversity and the wildlife. According to Wana (2009), climate change impact on lowland biodiversity for Southwest Ethiopia using climate model predicted that biodiversity of the area will suffer severe consequences of biotic attrition (that is, the net loss of species richness in the tropical lowlands caused by altitudinal range shifts in the absence of new species arriving), range-gap shifts and contractions, and extinction due to expected warming at the end of this century. The model also predicted that endangered and endemic species with restricted elevational ranges will disproportionately suffer from range contraction and extinction due to warming.

4.7.2.Temperature Rise Impact On Ethiopian Biodiversity

The temperature has been increasing annually at the rate of 0.2°C over the past five decades. Most climate change models predicted an increase in temperature from 2.1°C in 2050 to 3.4°C by 2080 (FDRE, 2007).This rise in temperature would accelerate the damage to the biodiversity and ecosystem, and threaten extinction in a given ecosystem if climate conditions change too quickly for them to adapt. In the afroalpine (highland) ecosystem of the country the temperature rise is more likely to push Gelada baboons to move up in the altitude in search of suitable conditions, resulting in their occupying increasingly limited and fragmented habitats (Dunbar, 1998).

Warmer temperatures have allowed pathogens, vectors, and hosts to expand their ranges, allowing pathogens to be present in new geographical locations and potentially infect new nave hosts, resulting in morbidity or mortality in wildlife, livestock, and humans in some cases. Rise in temperatures would also enable insects and pathogens to spread their range and increase their chances of surviving the winter. Invasive species thriving as a result of climate change are displacing native shrubs and grasses and transforming native shrub-steppe and grassland habitats.

Altitudinal and/or structural shifts in tree-line and tree island communities, earlier egg-laying dates for native birds, increased susceptibility and vulnerability of giant lobelia

(Lobelia rhynchopetalum) and heather moorlands to fungus, insect infestations, and frequent fire are all possible manifestations of temperature rise in the afroalpine and subafroalpine ecosystems (Amanuel et al., 2018). Long summer droughts would make places that were previously at risk of fire become areas with a continual fire threat, which is another effect of temperature rise. As summers get hotter and drier, forest fires are anticipated to occur more frequently; repeated forest fires have been documented in the Bale Mountains National Park (REDD+, 2017). Temperature increase with reduced precipitation will result in reduction of livestock reproduction and breed loss that may lead to genetic erosion of important adaptation traits. Increases in the frequency of droughts, floods and disease epidemics would increase the risk of mortality in the livestock population.

Climate change is causing a deficiency of rainfall and recurrent drought in Ethiopia that claims human life and affects biodiversity. Deficits in precipitation and drought would have a major effect on the biodiversity of the various ecosystems (MEFCC, 2015). However, the afroalpine ecosystem could be severely impacted due to its low adaptive capacity, low resilience to environmental variability, and high sensitivity to dry air. Precipitation deficits affect the water availability of afroalpine lakes, which are critical habitats for endemic birds like the Blue-winged goose and the Spot-breasted Plover, as well as many other regional and intercontinental migratory bird species (IBC, 2014). As a result, these birds would most likely be the first species to be affected by any qualitative or quantitative changes in afroalpine lakes as a result of climate change.

In general, according to (EPCC, 2015) climate change is expected to affect ecosystems in the followingways:

1. An increase in major ecosystem disturbances (ecosystem functions and processes);

2. Shifts in geographical ranges of some native plants and animals in the afroalpine and subafroalpine ecosystems;

3. Change in timing of life-history events for plants and animals;

4. Spread of invasive species and diseases;

5. Degradation and loss of habitats such as loss of stopover and breeding sites for migratory bird species in afroalpine and subafroalpine lake systems

6. Declines in species, populations, genetic erosion, extinction, or loss of biodiversity.

4.7.3. Climate Change Adaptation Strategies in Biodiversity

In order to prevent the harmful effects of climate change on Ethiopia's biodiversity, it is vital to develop strategies for reducing these effects through the creation and implementation of relevant policies. By comprehending this, several legal and institutional frameworks targeted at maintaining the country's economic success and mitigating the problem of climate change have been developed, one of which is its Climate Resilient and Green Economy (CRGE) launched in 2011. Further, the Sustainable Land Management Project (SLMP) has been the major flagship government project aimed at building natural resources in the country. The project's initial phase, known as SLMP-1, applied from 2008 to 2013, while its second phase SLMP-2, run from 2013 to 2019. In some parts of the country, the SLMP-1 program introduced sustainable land management techniques, which produced tremendous results in the rehabilitation of degraded regions that were previously uneconomical and unproductive.

Ethiopia has demonstrated conservation efforts as well as governmental initiatives to address climate change. Ethiopia has ratified a number of important international environmental treaties and protocols, including the Paris Agreement, the Kyoto Protocol to the United Nations Framework Convention on Climate Change, the United Nations Convention on Biological Diversity (CBD), and UNFCCC. Ethiopia has also created and carried out a variety of national initiatives and programs relating to climate change. It has also participated actively in international climate negotiations. Ethiopia is taking the required actions to put the two types of climate change responses into effect: adaptation and mitigation. Ethiopia created its National Adaptation Programme of Action (NAPA) and Nationally Appropriate Mitigation Action (NAMA), which were then presented to the UNFCCC in 2007 and 2010, respectively. This indicated an increasing level of understanding and concern among policy and decision-makers on the severity and impact of climate change on the environment and biodiversity. The concern is largely esteemed on the multi-dimensional nature of the impact of climate change to affect the social, cultural, economic, and environmental assets. In the livestock sector various strategic plans such as Livestock master plan, Livestock and fisher sector plan and sustainable land management plan (Ethiopia national determined contribution (NDC), 2021) were enacted to reduce the impacts of climate change on livestock diversity.

Toeffectivelyimplementconservation,sustainableuse,anddevelopmentofbiodiversity, and ensure fair and equitable sharing of benefits accrued from access to the country's genetic resources, Ethiopia has established and restructured some institutions in federal and national regional states. These include the re-establishment and restructuring of the Ethiopian Biodiversity Institute, the establishment of Regional Biodiversity Units, the Biodiversity Centre, and the Ministry of Environment and Forest. To combat climate change impacts, ensure biodiversity conservation, sustainable use, and development, as well as to safeguard fair and equitable sharing of benefits derived from access to the country's genetic resources,

CRGE in particular is the ambitious plan and considered the most relevant policy and program documented green economic growth through climate change adaptation; further other strategic plans such as Growth and Transformational Policy (GTPI & GTPII) can be considered an aggressive climate adaptation program by the country. The vulnerability reduction planned by the government in the CRGE includes reforestation of 3 million ha of land by 2030 (20% moist Afromontane, 60% dry Afromontane, 10% Acacia- Commiphora, 10% Combretum-Terminalia). The restoration of 5 million ha of land by 2030 and 9 million ha by 2050 were the conditional pathway goal (10% moist Afromontane, 60% dry Afromontane, 10% Acacia-Commiphora, 20% Combretum-Terminalia) (CRGE,2011).

Ethiopia has given proper consideration to the establishment and management of protected areas in order to preserve biodiversity and combat climate change. Currently, there are four biosphere reserves, 20 national parks, four wildlife sanctuaries, eight wildlife reserves, eight regulated hunting zones, and 58 National Forest Priority Areas (NFPAs) (Ethiopian wildlife conservation authority (EWCA), 2019). Protected areas are essential for preserving ecological services and biodiversity (soil erosion control, regulation of the hydrological cycle, drought and flood mitigation, carbon sequestration, watershed protection, pest and disease control, etc.). Therefore, the management of the country's current protected areas and new establishment in various ecosystems is essential for biodiversity preservation, socioeconomic development, and the mitigation and adaptation to climate change. Yet, considerable efforts will be required to expand and redesign protected area systems to ensure that they include sufficient area to accommodate management practices that both facilitate change and maintain large populations of species of concern. Ensuring the continued survival of species and ecosystems under changing climatic conditions requires not only adjustments to the extent and location of protected areas but also changes in the ways of managing them (Christian and Grace, 2013).

4.8. Infrastructures

Infrastructure refers to the basic systems and facilities that a country or organization needs in order to function properly. Infrastructure services including

i. Transport: Airports, ports, rail, road,

ii. Energy: Generation, transmission and distribution of electricity and gas including pipelines, and associatedinfrastructure,

iii. Water: Sanitation, irrigation, (transboundary) water resource infrastructure, water supply, waste (solid & liquid) treatment and management.

iv. ICT: Information and communication technology, including broadband, mobile network, satellite are central to the activities of households and to economic production.

The Commission for Africa made a persuasive case for the vital need to focus emphasis on creating and managing a sustainable infrastructure (transport, water, energy, and ICT) system in Africa at the 2005 G8 Summit in Gleneagles (UK) (ICA, 2018). Infrastructure development in Africa is crucial for fostering economic growth and raising Africans' living standards. It makes a substantial contribution to human development, poverty reduction, and achieving the Sustainable Development Goals (SDGs). Infrastructure investment has accounted for more than half of Africa's economic development over the previous decade, and it has the potential to contribute even more if the right conditions are in place (Azolibe et al., 2020).

Ethiopia has made tremendous infrastructure progress, and its infrastructure indices compare favorably to those of low-income countries. It has started an ambitious investment program to modernize its network of trunk roads and is putting in place a new road maintenance funding framework. Due to judicious attention on intermediate solutions such as traditional latrines, wells, boreholes, and stand posts, access to water and sanitation is fast expanding (from a very low base) (Torres et al., 2011). The country's biggest infrastructure problem is in the power industry, which will require an additional 8,700 megawatts of producing capacity over the next decade, more than tripling existing capacity. In terms of transportation, the fundamental task is to enhance Ethiopia's extremely low rural accessibility and guarantee that recent road network investments are properly maintained (Foster and Morella, 2010).

4.8.1. Development of Infrastructures

The infrastructure of all kinds, from power and water infrastructures to transportation and waste disposal systems, is essential to all human communities. Such infrastructure is already severely strained in emerging nations like Ethiopia due to population growth, rural-to-urban migration, high levels of poverty, and the need for more roads and automobiles. Aspects of climate change, some of which will be direct, are anticipated to interact with or intensify this existing strain. Extreme weather events may have an immediate effect by bringing down power lines, washing away roads and bridges, or overtaxing drainage systems. These effects may also be caused by changes in temperature or rainfall levels. Longer-term effects can sometimes be less visible; for instance, ground subsidence could happen if warmer temperatures cause drier soils. Given its reliance on fuels derived from petroleum, the predominance of individual transport modes, and long-established travel habits, the transportation sector poses a unique challenge.

To meet the demands of the rising population, Ethiopia's urban sectors require effective planning in solid waste management, green parks, and non-motorized transportation. As Ethiopia's urban population expands, its urban centers will encounter issues relating to sanitation services and pollution in industrial and urban regions. Because adaptation challenges are not currently addressed in the solid waste management plan, more work is required to address climate adaptation in solid waste management. According to the report on regional prioritization processes, only two regions were given priority under anywhere operations (Increasing resilience of urban systems) (Dire Dawa and Somalia). However, the participants of the recent federal and regional level consultation workshops confirmed that the component had widespread regional implementation, which was a requirement for creating an implementation roadmap for ETH-NAP. In comparison to the other five regions, the scale is comparatively greater in the Amhara, Oromia, SNPPR, and Tigray regions (as well as the two Administrative States, Addis Ababa and Dire Dawa). In reality, the execution of the infrastructure component benefits the vast majority of people living in urban and rural areas. Better energy, transportation, and employment prospects could be the anticipated short-term results, while Ethiopia could achieve middle-income status before 2025 in the medium- to long-term.

The benefits of implementing the planned infrastructure improvements will nevertheless make the country's inhabitants more adaptable to harsh weather events, which are predicted to become more common because of climate change. As envisioned in the various policies adopted, the government demonstrated a commitment to constructing low-carbon, high-resilience infrastructure and moving toward greener growth (Dawson and Spanngle, 2015).

According to Ethiopia's National Adaptation Program of Action (NAPA), the agricultural, water resources, and human health sectors will mostly negatively be impacted by climate change. NAPA additionally identifies the infrastructure sector as particularly vulnerable to climate change impacts. Prime Minister Abiy Ahmed of Ethiopia remarked in a morning address to members of parliament on 6/14/2022 that Ethiopia's concrete asphalt network had nearly doubled since the April 2018 change that brought him to power. Before the reform, the Ethiopian Roads Authority had built 13,000 kilometers of concrete asphalt roads, but after the reform, the Authority had completed 4,700 kilometers of roads and was now completing another 8,113 kilometers of asphalt roads. In addition, the budget has been allocated for an additional 9,102 kilometers of concrete asphalt roads, despite the fact that the actual work has been hampered by security concerns. According to Prime Minister Abiy Ahmed, Ethiopia's complete road network, including gravel roads, has grown from 127,000 kilometers to 165,000 kilometers since the reform. Over the last four years, the city Addis Ababa has created 151 kilometers of asphalt roads, 470 kilometers of cobblestones, and 116 kilometers of walkways.

According to the World Bank collection of development indicators, compiled from officially recognized sources, the length of the trunk network is more than adequate. Ethiopia's road density indicators (ratio of the length of the country's total road network to the country's land area) look relatively low by some standards, but the trunk network provides basic regional and national connectivity. It links the capital to the coast as well as the international border crossings and the internal provincial capitals. Road density (km of road per 100 sq. km of land area) in Ethiopia was reported at 4 sq. Km in 2007. The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads. Paved roads (crushed stone, and hydrocarbon binder or bituminized agents, with concrete, or with cobblestones) in Ethiopia were reported at 13.7 % in 2007 as a percentage of all the country's roads, measured in length. Total road network (km) in Ethiopia (Figure 122) was reported at 44359 km in 2007, according to the World Bank collection of development indicators in June of 2022. Total road network includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country. A motorway is a road designed and built for motor traffic that separates the traffic flowing in opposite directions.

Figure 118 Ethiopia - Roads, Total Network (km), historical data 1990-2007

According to World Bank collection of development indicators in 2022, access to electricity (% of population) was reported at 51.09 % in 2020 (Figure 123) power transmission and distribution losses (includes between sources of supply and points of distribution and in the distribution to consumers, including pilferage) losses (% of output) was reported at 18.65 % in 2014. Access to electricity, urban (% of urban population) in Ethiopia was reported at 93.25 % in 2020.

Figure 119 Ethiopia - Access to Electricity (% of Population) 2022 Historical data 1990-2020

4.8.2.Advancement, Infrastructure Services

Technologies for adaptation are related to climate services because they make information more accessible and give individuals more options for coping with climate threats. In addition to early warning systems, insurance plans, and research and development are covered by this implementation component. In order to strengthen the role of climate information in resilience, the GoE is currently preparing the National Framework for Climate Services (NFCS) as part of the Global Framework for Climate Services (GFCS). The NFCS is a coordinating mechanism that enables the development and delivery of climate services at the national level. The NFCS will also bring about improved risk management through the incorporation of science-based climate information and prediction mechanisms into the decision and policy-making process of the Ministry of Water, Irrigation and Electricity of Ethiopia (MoWIE, 2019). In addition to climate services, emerging technologies that can increase the resilience and adaptability of households and communities also fall under the category of adaptation technologies. It is crucial to remember that adaptation technology might include climate services. Either UNFCCC (2006) states that climate adaptation technologies can come in hard or soft varieties, such as improved irrigation systems or seeds that can withstand drought. As with early-warning systems that combine hard measuring devices with soft knowledge and skills that can increase awareness and prompt appropriate action, they could also use a combination of hard and soft.

Ethiopia is vulnerable to the impacts of climate change mainly due to its geographical location, rapid human population growth, heavy dependence on agriculture and natural resources for subsistence, widespread poverty, and limited resources (human, financial, technical, technological, institutional, and infrastructural (Zegeye, 2018). In the period 1999–2008, droughts and flooding affected nearly 21 million people (19.7 million by droughts and the remaining by flooding) in Ethiopia (CRED, 2009). Furthermore, flooding in turn causes significant damage to infrastructure especially if the rains occur around harvest time (World Bank, 2011 and Ekbom, 2013). Climate models show warming in all four seasons over Ethiopia, which may result in more frequent heat waves and heavy rainstorms that can destroy energy infrastructure, for example, power transmission and distribution lines (ODI and CDKN, 2014).

Ethiopia presents a significant challenge in developing infrastructure that reduces GHG emissions while also making these systems, and the populations they service, more resilient to extreme weather, which is predicted to become more common as a result of climate change (Kennedy et al, 2012). To put it another way, Ethiopia has to invest significantly more in low-carbon, high-resilient infrastructure in order to transition to a greener growth path.

Figure 120 Ethiopia - Access to Clean Fuels and Technologies for cooking (% Of Total Population), historical data (2000-2016)

Green infrastructure will necessitate significant investment (for example, 10% annual growth rates will necessitate 14% annual hydroelectric power additions), and green infrastructure has high direct costs and long pay-back periods (OECD, 2013). There is little development on using Clean Fuels and Technologies for cooking (% of total population) in Ethiopia as reported at 3.51% in 2016 (Figure 124), according to the World Bank collection of development indicators.

In truth, climate change is more than a hoax; it is a reality, and the government must develop suitable and effective adaptation policies to handle climate change's impact on infrastructure. Furthermore, all stakeholders should actively participate in reducing climate change risks. There are a few suggestions to improve the research based on the findings in this project data is very essential for analysis and decision making. However, there is no adequate Infrastructure data in Ethiopia; therefore, the improvement of the database is highly required.

4.9. Capacity Building

Ethiopia is among a few countries committed to build a green climate resilient economy by 2030. Hence, a CRGE was developed to address climate change mitigation in the crop and livestock, forest, energy and transportation, and industry sectors. Drawing on the CRGE initiative the first Nationally Determined Contribution (NDC) was launched. NDC was targeted to limit net Greenhouse Gas (GHG) to 145 Mt CO_2e by 2030. This constituted a 255 Mt CO_2e reduction from the projected business-as-usual emissions in 2030 or a 64% reduction from the scenario in 2030.

The Ethiopian government recognizes the importance of sectoral capacity building to raise awareness and identify sectoral feasible adaptation options to properly respond to the impact of climate change. Accordingly, the sector's capacity gaps were identified and action plans were developed. Among factors affecting the effort of stakeholders' capacity development were weak coordination and collaborations of stakeholders, lack of resources (technological, finical, skilled manpower) & clear roles and responsibilities to address capacity gaps, lack of clear and harmonized policy and strategies, weak partnership and knowledge management system and information sharing platforms. In general, the Ethiopian government thought developed various initiatives (e.g. CRGE, NDC) to build sectoral capacity to deal with climate change; the country is vulnerable to climate change particularly due to weak adaptive capacity and depends on a climate-sensitive economy. The government effort to integrate climate change adaptation with the national development plan is not at the level expected level and hence, climate change and extremes translated into food security.

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5. CHAPTER FIVE: OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENT OF THE OBJECTIVE OF THE CONVENTION

This section describes the steps taken to integrate climate change; activities relating to technology transfer; information on climate change research and systematic observation programs; information on education, training and public awareness; capacity–building; information and networking and gender mainstreaming. These items are treated on a stand–alone basis or collectively whenever they are closely linked.

The report is structured into eight sections. The first section covers the steps taken to integrate climate change in the relevant planning processes and activities geared towards the implementation of the convention. The second section describes the activities related to technology transfer, including technology needs assessments and access to environmentally sound technologies (ESTs), and the measures related to enabling the environment for their development.

The third section delivers a description of the information on climate change research and systematic observation programs including research to adapt to and mitigate climate change and the country's participation in, and contribution to, activities and programs, as appropriate to its national, regional and global research networks.

The fourth section emphasizes information on climate change education, training and public awareness practice and attempts to describe Ethiopia's effort to strengthen the mainstreaming of climate change in education, training and public awareness. While the fifth section deals with the status of capacity–building activities at the national, regional and sub–regional levels to strengthen the coordination, dissemination and sustainability activities, the sixth section focuses on the efforts to strengthen information and networking within different sectors in the country and the region. The seventh section is devoted to gender mainstreaming.

5.1. Integrating climate change in planning process

Early actions on climate change have allowed Ethiopia to prepare for short– and long–term adaptation and mitigation actions closely linked with national environmental policies. Under this section issues related to integrating climate change into relevant social, economic and environmental policies along with their role played in the relevant planning processes in Ethiopia taking short–, medium–, and long– term development plans and poverty reduction strategy.

5.2. Environmental Policy

The Federal Democratic Republic of Ethiopia prepared the environmental policy (EPA, 1997) of the country to give overall guidance in the conservation and sustainable utilization of the country's environmental resources. The general aim of the policy focuses on enhancing the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human–

made and cultural resources and the environment to meet the needs of the present and futuregenerations.

The policy attempts to provide general guidance on the conservation and sustainable utilization of resources. The areas that were covered in the policy include: soil, forest, woodlands, biodiversity, water, energy, minerals, the urban environment, environmental health, industrial pollution, atmospheric pollution, and the cultural and natural heritage. The policy also included other cross–sectoral issues such as population and the environment, community participation and the environment, and tenure and access rights to land. All the aforementioned issues are directly and indirectly contributed towards or influenced by climate change. To accommodate this aspect the policy is based on the following underlying key principles:

- Healthy environment accompanied by sustainable economic production systems;
- Development using the management of renewable resources;
- Minimized use of non-renewable resources;
- Promotion of appropriate technologies using renewable and non-renewable resources;
- Incorporating environmental and social costs resulting from development practices into public and private sector planning;
- Supporting community resource users to sustainably manage their own environment;
- Ensuring settings for sustainable natural resource management towards ensuring social equity;
- Increased awareness of environmental promoted by policy makers;
- The integrated implementation of cross–sectoral policies and strategies shall be seen as a prerequisite to achieving the objectives of this Policy.

5.3. Economic Policy

Ethiopia's economy grew at a double–digit rate over the 2010 to 2018 period. The macro–economic policy objectives during this period were sustaining rapid and inclusive economic growth within a stable macroeconomic environment including maintaining a stable and low inflation, ensuring structural transformation in the economy, consolidating the gains in human development and reducing poverty and unemployment; as well as enhancing the share of investment and domestic saving in GDP. Within these basic objectives, implementation of the fiscal policy was carried out so as to maintain sustainable level and financing of fiscal deficit through effective mobilization of domestic revenue, efficient utilization of resources, and managing public debt within a stable macroeconomic environment.

Thus, during this period, the policy aimed to spur economic structural transformation and sustain accelerated growth towards the realization of the national vision to become a low middle–income country by 2025. It focused on ensuring rapid, sustainable, and broad–based growth by enhancing the productivity of the agriculture and manufacturing sectors, improving the quality of production, and stimulating competition within the economy. Moreover, throughout this period, the government of Ethiopia made a significant public investment in infrastructure, and foreign direct investment that was encouraged through a series of incentives such as tax exemptions, tax holidays, and the construction of industrialparks.

The government accelerated its investment on infrastructure during the GTP I period (2010-2015) and early periods of the GTP II period (2015-2020) (FDRE, 2014; FDRE, 2016). Furthermore, the government was in the process of privatizing many of the state–owned businesses and moving toward a market economy. The telecom, financial and insurance services, air and land transportation services, & retail are considered as strategic sectors and are expected to remain under state control for the foreseeable future.

In line with these development plans, the issues of environment and climate change are explicitly indicated in the first GTP that was prepared along with the Climate Resilient Green Economy (CRGE) strategy. The GTP I document clearly indicated the importance of environmental conservation for sustainability of development. In this context, building a carbon neutral and climate resilient economy and enforcement of existing environmental laws are priority actions in connection to environmental conservation.

5.4. Integrating Climate Change in Planning process

While Ethiopia strives to achieve its determination of reaching middle income status before 2025, the national development is challenged by the environmental consequences of economic growth and the presence of climate change. Taking this fact into consideration, the government of the Federal Democratic Republic of Ethiopia crafted the CRGE strategy (EPA, 2011), the green economy strategy, and Ethiopia's National Adaptation Plan (NAP–ETH) (EEPA, 2019).

Apart from this, cognizant of the threats posed by climate change and the decisions under the UNFCCC, the government prepared the "National Policy and Strategy on Disaster Risk Management" (FDRE, 2013). The objective of this policy is to reduce disaster risks and potential damage caused by a disaster through establishing a comprehensive and coordinated disaster risk management system in the context of sustainable development. This policy is coined through building resilience to withstand impacts of hazards and related disasters and by providing timely and appropriate response to disasters.

Furthermore, Ethiopia was one of the first countries to submit its Intended Nationally Determined Contributions (INDC) in June 2015 (FDRE, 2015). This INDC is aligned with the national development plan and anchored on the CRGE vision and strategy of Ethiopia that was developed through an inclusive and participatory process. The INDC includes a 68% decrease in carbon emissions by 2030 under the Business-as-Usual target covering key agriculture, forestry, transport, electric–power, industry, and construction sectors. It highlights the importance of the participation of and benefits for vulnerable groups within the population. On the other hand, the green economy strategy elaborates the green components of the CRGE and analyzes the major sources of GHG emission along with identified concrete actions to reduce emission while making development progress in each sector.

These policies, strategies and plans describe a new model of development that integrates measures of economic performance, such as GDP growth, infrastructure development, poverty reduction, job creation, and social inclusion, with those of environmental performance, such as improving resilience to climate shocks, mitigation of GHG emissions, reducing biodiversity loss and ensuring access to clean water and energy. Their goals are reducing vulnerability to the impacts of climate change by building adaptive capacity and resilience.

The NAP–ETH aims to strengthen holistic integration of climate change adaptation in Ethiopia's long–term development pathway, supported by effective institutions and governance structures, finance for implementation and capacity development and strengthened systems for disaster risk management and integration among different sectors. It provides further details on the country's strategies for adapting to climate change. The plan and its implementation are guided by the principles of participation, coherent interventions, stakeholder empowerment, gender sensitivity, equitable implementation and partnership.The CRGE has been long–drawn–out to include a practical framework to support the mainstreaming of gender equality and social inclusion in the operations of Ethiopia's CRGE Facility. Thus, came–up with the document entitled "Climate Resilient Green Economy (CRGE) Facility Gender Mainstreaming Strategy (FDRE, 2020a)" for gender mainstreaming.

The purpose of this strategic document is to enhance the institutional capacity of the Ministry of Finance and Economic Cooperation in gender mainstreaming in climate change adaptation and mitigation interventions financed through the CRGE Facility. Moreover, this framework is designed to provide strategic guidance for addressing gender inequalities in the operations of the CRGE Facility and improve the accountability mechanisms on how gender mainstreaming can be ensured in climate finance. In general, the gender mainstreaming strategy provides strategic guidance for gender mainstreaming in the operations of the CRGE Facility; improves accountability mechanisms on gender mainstreaming in climate finance, and develops a guide for gender mainstreaming and gender action plan for implementation.

In addition to the CRGE, NAP–ETH, and green economy strategy, Ethiopia has undertaken several strategic and programmatic adaptation and mitigation actions. The strategies and plans which are enabling the actual implementations of climate actions include:

- Nationally Appropriate Mitigation Actions (NAMAs) (2007),
- Agriculture and Forestry Climate Resilience Strategy (2015),
- Intended Nationally Determined Contribution (INDC) 2015,
- Sustainable Land Management Program II (SLMP II) 2013
- National Adaptation Program of Action (NAPA),
- National Energy Policy(1994),

- Ethiopian Program of Adaptation to Climate Change (2010),
- REDD+ strategy,
- National Policy and Strategy on Disaster Risk Management, (2013)
- Water and energy climate resilience strategy 2015,
- Guideline for mainstreaming CRGE 2018,
- Sectoral Climate Resilience Green Economy Strategy (2015);

These documents have components that are directly linked to climate change adaptation and mitigation. For instance, the NAPA of Ethiopia helps to lower GHG emission, lessen air pollution, and increase the use of public transportation through the Addis Ababa Light Rail Transit. Moreover, the NAPA promoted soil organic sequestration using climate smart approaches. On the other hand, the National Policy and Strategy on Disaster Risk Management clearly indicated that disaster risk management activities shall be implemented in a coordinated and integrated manner with social problems and climate change related risks and vulnerabilities reduction activities. On similar tract record, Climate Resilience Strategy in Agriculture and Forestry focused on community mobilization for integrated watershed management campaign, sustainable land management program, productive safety net program and development response to displaced impacts project are promoting natural resource management actions which will contribute to building resilience to climate change in the natural resources sub-sector.

In order for climate change adaptation to be sustainable and implemented on a broad scale, it must be "mainstreamed" into the policy apparatus of governments. Mainstreaming climate change is the process of integrating adaptation and mitigation objectives within development agendas. In other words, climate change risks are not addressed through separate initiatives but through the ongoing development policy–making, planning, and activities across all sectors. Through mainstreaming, climate change adaptation policies do not need to be developed for specific sectors, but rather facilitate their development and implementation as part of existing sectoral policies. Through mainstreaming climate change into policies, plans, and strategies, resources will also be used efficiently, avoiding cross–programing and multiple similar activities being implemented by different agencies. Mainstreaming climate change adaptation into development activities will also reduce policy conflicts. Using integrated budgeting, additional financial leverage can also be achieved. Accordingly, Ethiopia's NAP initiative is part of its grand ambition of mainstreaming climate change adaptation into current and future development plans, across sectors and levels.

In order to strengthen the implementation of the NAP–ETH, the government of Ethiopia has developed the "Resource Mobilization Strategy for Ethiopia's National Adaptation Plan (FDRE, 2020b)". This strategy aims to help the government to identify and scale–up financing for adaptation. It identifies financing gaps, explores financing options, and sets out next steps for the short– and medium–term. The strategy provides important information for potential supporters and implementers of adaptation actions, including national, regional, and Woreda government departments and bureaus, and bilateral and multilateral development partners.

According to the aforementioned strategy, the NAP–ETH estimates that Ethiopia will require nearly USD 6 billion per year (USD 90 billion total) to implement the adaptation options from 2015 to 2030 (FDRE, 2020b). The document notes that this amount is needed proportionally for each of the 18 adaptation priorities, indicating that USD 330 million per year is required for each of the 18 adaptation options (FDRE, 2020b). Given the significance of the effects of climate change to all facets of life, integrating the phenomenon as a cross–cutting issue into national development plans along with monitoring the implementation of the country's NAP–ETH, CRGE strategy and other policies and core strategies is shouldered by the Environment, Forest and Climate Change Commission (EFCCC).

Ethiopia's EFCCC and the Ministry of Finance and Economic Cooperation, develop standardized guidance and provide ad–hoc, sector–specific support in regards to Ethiopia's climate change adaptation and resilience strategies. In order to successfully integrate, operationalize, and implement the CRGE strategy, the complementary green economy strategy and climate change mitigation and adaptation strategies, sector ministries (those critically impacted such as ministry of Agriculture, Ministry of Industry, Ministry of Water and Energy, Ministry of Transport, Ministry of Mines) have established Environment and CGRE directorates, and other sectors appointed a team or focal person responsible for environmental safeguarding, planning, and implementation. The established directorates/team/focal persons in the ministries are directly accountable to the minister. This provides strength for the successful follow-up of integration and implementation of climate change adaptation and mitigation activities. Moreover, the Commission has developed a guideline entitled "***Integrating the Climate– Resilient Green Strategy in Sector Development Plans*** (FDRE, MoEFCC, 2014)" that helps to integrate climate change adaptation and mitigation activities in their annual and medium-term planning process. Moreover, the Commission provided capacity building training and encouraged sector ministries to adopt and prepare their own guidelines taking their existing situations into consideration. Accordingly, for example, the Ministry of Industry in collaboration with USAID crafted the "***Green Manufacturing Strategy***" and "***Energy Efficiency Strategy for the Ethiopian Manufacturing Sector***" which promotes energy efficiency with low emission (FDRE MoI, 2019a; FDRE MoI, 2019b).

Apart from facilitating the integration of climate change adaptation and mitigation in their plans, the implementation of the plans is monitored jointly by the Commission and all sector ministries through quarterly and annual performance reports and monitoring forums to exchange the required information to improve implementation. The planning process in each ministry and sector departments attempts to link the mitigation and adaptation activities with the national development programs and projects involving consultation with key stakeholders, NGOs, government ministries/agencies, research institutions and civil society organizations. This is thoroughly checked through a rigorous appraisal process involving a number of back–and–forth within the ministries by the CRGE directorates/team/focal persons for including the key aspects of the CRGE strategy before finally communicating it to the Commission for concluding remark andapproval.

The plans have direct links to the adaptation and mitigation plans included in the CRGE, ETH–NAP, and INDC and take the eighteen NAP–ETH major adaptation options. The eighteen options are defined to address major challenges of the country that are easily exacerbated by climate change impacts. For instance, the plan prepared by the ministry of agriculture focuses on enhancing crop and livestock productivity by selecting resistant and tolerant varieties through switching and/or diversification, selection and breeding and by diversifying varieties. Specific to crops, the plan considers effective systems for increased use of organic fertilizers and appropriate mechanization. For livestock, improved breeding and feeding systems and improved pasture/grazing management will be realized along with enhanced veterinary services. For both crops and livestock enhanced water availability, use of appropriate agricultural technologies and enhanced soil and water conservation methods.

On the other hand, safeguarding landscapes and watersheds is coined for ensuring and strengthening sustainable natural resources management. This adaptation option focuses on safeguarding hydropower dams; improving ground water recharge; minimizing downstream flood risks; and rehabilitating degraded lands. At this time, the government of the Federal Democratic Republic of Ethiopia is undertaking structural reform, which is modifying the powers and duties of the executive organs. Accordingly, the EFCCC is organized into the "Environment Protection Authority", where the powers and duties entrusted to the MEFCC under Forest Development, Conservation and Utilization Proclamation No. 1065/2018 is shifted to the Ministry of Agriculture (FDRE, 2021)

Moreover, according to this same proclamation, initiating policies, strategies and laws with respect to development, climate change and environment as well as coordinating, supporting and follow-up of climate change and environment activities are vested in the Ministry of Planning and Development. Finally, the previously organized directorates/teams/focal persons in the sector offices are getting attached to each sector individually and reporting to the ministry.

5.5. Development and transfer of environmentally sound technologies

Offsetting the causes and impacts of climate change requires environmentally sound technologies for the mitigation and adaptation strategies. Article 4 of the Convention recognizes the importance of technology transfer that is clean or green as a key means to combat anthropogenic climate change. Thus, technological innovations are helpful not only in reducing emission but they are also essential in adapting impacts as well.

Hence, the adoption and dissemination of technology between and among nations and non–state actors is critical in responding to the impacts of climate change.

5.6. Technology needs

Ethiopia's CRGE strategy, the Green Economy strategy and ETH–NAP clearly articulated a low carbon emission and climate resilient development that requires advanced technologies. Accordingly, in 2007, the first technology needs assessment (TNA) to identify, select and prioritize technologies that were needed in order to effectively mitigate and adapt to climate change (FDRE, 2007). Moreover, the assessment was helpful to identify and exploit local, national and international opportunities for technology transfer.

In 2015, the nine regional governments and the two city administrations of the country have conducted their perspective regional TNA that revealed the need to promote:

- Green infrastructure and sound watershed management, which can reduce stormwater runoff, mitigate the urban heat island effect through energy–efficient appliances and equipment;
- technologies related to Climate–Smart Agriculture (CSA) and reducing livestock numbers by improving productivity;
- technologies geared toward solar powered drip irrigation and sprinkler based irrigation for water stressed areas;
- improved management of fertilizer application, amount, types and methods and time of application
- technologies for improving animal feed, modern apiculture, and flood and drought early warning systems for crop production;
- drought tolerant and early maturing crop varieties along with development of small scale irrigation and water drilling and harvesting technologies in arid, semi-arid, and dry sub-humid areas;
- technologies that focus on expanding bio–fuels, conserve energy through efficiency and management improvement, recycling of materials and switching energy sources were required by the industry sector;
- technological advances for the promotion and expansion of green energy sources such as solar energy; geothermal energy; wind energy; and technologies capable of generating electric energy from solid waste;
- technologies that promote alternative fuel, alternative means of transport, compact vehicles powered by electricity, efficient vehicles, and infrastructure and systems improvement;

5.6.1. Ethiopia's Technological Progress

The Government of Ethiopia already spends a substantial portion of its annual budget on infrastructure and the provision of social services, which contribute to addressing the negative impacts of climate change by reducing emissions and vulnerabilities. Although there are hurdles to the transfer of technologies, Ethiopia is engaged in activities of incubating local innovation, adoption of technologies taking the local conditions into consideration, and transfer of technology helpful to tackle climate change as well. While the Ministry of Water and Energy established the "Ethiopian Rural Energy Development and Promotion Center (EREDPC)" by proclamation No. 269/2002 for promoting efficient and environmentally sound energy technologies in a sustainable manner, the national biogas dissemination scale–up program has successfully distributed a total of 12,293 household size bio–digester nationally. The EREDPC has been conducting research to:

- conduct research to convert invading, exotic, and harmful plant species such as water hyacinth and Prosopis juliflora to energy source through carbonization & production of brackets using crop residue;
- promote the import of certified energy saving utensils and LED (light emitting diode) bulbs;
- disseminate energy efficient LED bulbs to the community at low cost when they return their power–inefficient incandescent bulbs;
- transform traditional stoves into modern/improved and energy saving stoves (these improved/modern stoves are known for reduced non–renewable biomass consumption required to provide thermal energy for domestic cooking;

In relation to the improved/modern cooking stoves, a project run by Oromia Coffee Farmers' Cooperative Union; Horn of Africa Regional Environment Centre and Network; Oromia Water, Irrigation and Energy Bureau; and Fair climate Fund, in Oromia regional state with project life time of seven years was reported to sequester an estimated annual CO_2 by 43,032 tCO_2 with co–benefits of reduced deforestation, reduced health risk, job creation, increase coffee productivity, enhance coffee export market and generate fair–trade carbon. Apart from promoting energy technologies via the EREDPC, the Ministry of Water and Energy is engaged in:

- expanding wind farms, geothermal energy, hydropower plants, and solar energy;
- encouraging wise use of electricity by increasing the electricity tariffs;
- generating electricity from Addis Ababa town waste via "Reppie waste–to–energy plant"; and
- cloud seeding technology to initiate rain in collaboration with NMI,

On the other hand, the Ministry of Agriculture has been promoting:

- CSA expansion from farm level to village level;
- Water spreading weirs technology in moisture deficient areas (WSW);
- Rain–water harvesting methods in moisture deficient and water poor areas;
- Desho grass (indigenous grass to Ethiopia) for biological soil & Water conservation (SWC);
- Climate–smart livestock system;
- Promote appropriate small–scale machinery (2–wheel tractors) to improve planting, harvesting, milling and transport among smallholder farmers

Besides these iconic activities, the ministry of agriculture developed the CSA Strategy and CSA manual for implementing the Sustainable Land Management Program (SLMP). The strategy is developed based on context analyses of Ethiopian agriculture and technological adoption. The aim is to strengthen the role of the Ministry of Agriculture in addressing vulnerabilities facing the agriculture sector under changing climatic conditions through institutionalizing CSA. The context analysis of CSA included the vulnerabilities of the agriculture sector; entry points for CSA interventions; review of policy documents related to agriculture and climate change; review of scientific literature on CSA approach and the status of CSA practices in Ethiopian agriculture; the opportunities and challenges of mainstreaming CSA. What remains to be done with CSA is creating awareness about the policies and promoting their implementation at all levels. One way of doing this could be mainstreaming the policies into agricultural extension and research. Moreover, establishing a legally binding institutional framework for greater coordination and integration among institutions, and synergy among programs/projects is vital.

In the broader Ethiopian context, climate–smart practices and technologies are being implemented within the framework of integrated watershed management, which incorporate a broad range of practices in crop and livestock production including agroforestry, crop rotation and intercropping as well as broader soil and water conservation measures such as soil/stone bunds, terracing, infiltration ditches, and tie–ridges among others (Melaku Jirata, 2016). Moreover, the council of ministers established the "Agricultural Transformation Agency (ATA)" to support the transformation of Ethiopia's smallholder farmers into commercialized actors with greater incomes, inclusiveness, resilience, and sustainability.

In terms of research, the Ethiopian Institute of Agricultural Research (EIAR) and its regional research institutes, federal and regional research centers, as well as universities constitute the National Agricultural Research System (NARS) in Ethiopia, whose principal aim is to generate and promote the adoption of information, knowledge, improved practices and technologies that increase agricultural productivity. EIAR's work related to CSA includes climate modeling; conducting on–farm trials of new varieties; and the testing of agrometeorological tools such as Agro–weather Decision Support System (DSS) to improve farmers' access to weather information and hence support adaptation efforts. International Livestock Research Institute (ILRI) and International Water Management Institute (IWMI) are working on topics such as biogas from dairy waste management, soil and water conservation, agroforestry and conservation agriculture. For example, the International Maize and Wheat Improvement Center (CIMMYT) is implementing the project on Sustainable Intensification of Maize–Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA), which is conducting research on and promoting maize legume intercropping.

The Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI) program focuses on identifying appropriate small–scale machinery (e.g. two–wheel tractors) to improve planting, harvesting, milling and transport among smallholder farmers. Both projects are funded by the Australian Center for International Agricultural Research (ACIAR) along with other partners (Feed the Future, 2017). The Water and Land Resource Center (WLRC), associated with the Addis Ababa University engages in research activities related to watershed and integrated landscape management, including implementation of sustainable land management (SLM) practices to increase productivity, rehabilitation of degraded lands, and management of the natural resources base.

The Ethiopian Environment and Forest Research Institute (EEFRI), established in 2015, is also conducting research related to agroforestry, forest product utilization and climate change, among others. Haramaya University is also set to become a key CSA institution as the host for the soon to be established African Center of Excellence in CSA and Biodiversity Conservation, which will aim to produce research and technically skilled personnel on CSA for the Eastern and Southern Africa regions; with master's programs being established in CSA as well as Biodiversity and Ecosystem Management.

On similar tract records of technology transfer, the Ministry of Transport and Logistics has been engaged in promoting the manufacturing of electric cars and motor bicycles; electric train for mass transport in Addis Ababa; and electric trains to the import–export corridor of Ethiopia. What is more, the Ministry of Industry has been engaged in establishing standard industry parks consisting of technologically advanced and modern industrial wastewater treatment plants. In addition to this, the ministry decided by its policy instruments to allocate 10% of the industrial park areas for green-area and adoption and innovation of low emission–energy efficient technologies for manufacturing of goods and services.

Last but not least, the Ethiopian Wildlife Conservation Authority has been engaged in building the capacity of its own staff technologically through Early Warning System for Forest Fire, carbon stock measurement techniques, GIS for safeguarding protected areas, conducting Environmental and Social Impact Assessment using advanced technologies, and different techniques of soil and water conservation schemes. While the Government has continuously committed to facilitate the identification of relevant environmentally sound technologies and knowledge in most sectors of its economy, the adoption, diffusion and application has remained low mainly due to financial constraints, limited capacity and awareness amongst users. The following table summarizes the financial flows in detail for the period 2014 to 2018.

Table 70 :Detail financial flow of grant, technical assistance and loan for the years 2014 to 2018

Description	Climate Relevance	Recipient sector	Amt $ million	Type
Agricultural Technology Support	Mitigation/adaptation	Agriculture	1.32275	Grant
Promotionofgreenenergy(wind,solar,hydropower, geothermal) includingpromotingsustainablerural energy technology for household and productive use	Mitigation/adaptation	Energy	263.728	Loan
Degraded Land Rehabilitation as a base of Sustainable Management of NaturalResources.	Mitigation/adaptation	Agriculture	0.532	Grant
Effective Irrigation for sustainable agricultural production	Mitigation/adaptation	Agriculture	77.763	Grant
Enhancement of Quality and Extent of Extension servicesand AgriculturalConsultancyDevelopment	Enabling activity	Agriculture	0.302	Grant
Climatesmartagriculturerelatedactivitiesincluding implementation andmanagement	Mitigation/adaptation & Enabling activity	Multisector	20.577	Grant
GreeningAgriculturalTransformationinEthiopia(GATE)	Mitigation/adaptation	Multisector	38.147	Grant
CRGEfacilityincludingForestLivelihoodsProgram;Forest &LandscapeRestoration;MRV;ClimateInformation andEarly WarningSystems;LandscapeManagement;	Mitigation/adaptation & Enabling activity	Forestry, agriculture & multisector	81.642	Grant, Technical Assistance
WasteManagement–SendafaSanitaryLandfill-Addis Ababa	Mitigation/adaptation	Multisector, water supply & sanitation	22.097	Loan

Natural Resources conservation and sustainable management including Biospheres and capacity building	Mitigation/adaptation & Enabling activity	Multisector, water supply & sanitation	134.972	Grant, Technical Assistance
Sustainable land management	Mitigation/adaptation	Agriculture	219.334	Grant, Technical Assistance
Sustainable Development of the Protected Area System in Ethiopia	Mitigation/adaptation	EWCA	5.561	Grant
Enabling Pastoral Communities to adapt to climate change & restoring range land environments & strengthening droughtresilience	Adaptation	Pastorals Development	127.789	Grant

5.7. Information on climate change research and systematic observation program

A well–functioning climate service has the potential to inform a range of both short and long–term decisions, contributing to the resilience of governments, organizations, and individuals to current climate variability while also preparing for an uncertain future that may look different from today. Thus, timely weather and climate forecasts play a pivotal role in mitigating the negative impacts of severe weather and extreme climate events through proper planning of the anticipated weather or climate events. These can only be achieved through well–organized systematic observation, monitoring and analysis of weather and climate parameters. Taking this fact into consideration, the Government of Ethiopia established the former National Meteorological Agency by proclamation No. 201/1980. This same agency experienced a number of nomenclature and structural changes and was renamed recently as National Metrological Institute (NMI) that represents the country in national, regional and global meteorological service deliberations. At present, the NMI of Ethiopia is responsible for climate and hydrological monitoring. The institute is engaged in various systematic observation and research activities related to national, regional and global climate change. The institute is structured into one Branch Meteorological Service Center Coordination Office and 11 sub–national branches of meteorological service centers. The mandate of NMI is broad and includes:

- Establish and operate a national network of meteorological stations designed to represent various climatic regions of Ethiopia and to satisfy the needs of various national development plans and activates;
- Collecting all meteorological data and exchange the data in accordance with international agreements to which Ethiopia is a party;
- Establish and operate communication systems, in accordance with the law for the collection and dissemination of meteorological data;
- Publish and disseminate analyzed and interpreted meteorological data and meteorological forecasts;
- Give advance warning on adverse weather conditions; disseminate advice & educational information through the mass media; & provide meteorological services to anyperson;
- Control air pollution and maintain the natural balance of the air in the country;

Currently, Ethiopia has a network of 1,539 (increased by 386 since the second national communication) fully functional meteorological and climatological stations run by NMI. Out of the total fully functioning meteorological stations 1220 are conventional stations, 286 are automatic weather stations, 2 upper air stations, 1 radar, 3 air pollution, and 27 airport electronic stations (NMA, 2020). The 286 operational automatic weather stations measure air temperature, wind speed, wind direction, relative humidity, rainfall and global radiations. It takes a measurement sample every minute and the statistics of 15 minute measurement are recorded. General Packet Radio Service (GPRS) telemetry communication is used to send data directly to the central station in real time based on the GPRS connection quality.

The system also logs six (6) month data at remote stations, depending on the size of the variables collected. High resolution, minimum human error, automatic digitization and transmission of the data and remote monitoring of the stations are the advantages of automatic weather stations. NMI also maintains an upper air sounding station and primary data receiver systems for METEOSAT and NOAA satellites at Addis Ababa. At present, the institute is monitoring air quality in three towns; namely Addis Ababa, Hawassa and Adama.

The NMI provides routine information on current climate conditions in the country, including monthly and seasonal climate outlooks. The institute also provides climate information services (CIS), which is seen as one mainstream strategy for climate risk mitigation strategy. With the availability of CIS from either indigenous knowledge systems or meteorological information, farmers are well-informed about rainfall distribution patterns; intensity and frequency; wind storms and extreme events like droughts which enable them plan their agricultural activities effectively and efficiently. Critical planning decisions such as when to start land preparation, when to plant, crop variety selection, schedules for fertilizer application are all tied to receiving downscaled seasonal forecast information.

Ethiopia actively participates in the World Weather Watch (WWW) program of the World Meteorological Organization (WMO) by providing daily weather observations. Ethiopia also cooperates with regional organizations, such as the African Center for Meteorological Applications and Development (ACMAD) and the IGAD Climate Prediction and Application Center (CPAC) in the field of climate and meteorology. The institute has updated its meteorological stations network master plan for 2021 – 2030 that attempts to improve station distribution to assure and provide representative, accurate, and reliable climate information for its users. Moreover, for a country like Ethiopia, whose economy and the livelihoods of millions of its citizens are dependent on the weather and climate, designing and implementing an overarching framework for climate services is of paramount importance. Cognizant of this fact, the NMI developed Ethiopia's "***National Framework for Climate Services (NFCS) Strategic plan*** (FDRE, MoWIE,2021)" that aims to help all sectors achieve their development and adaptation goals inthe face of a variable and changing climate.

The NFCS helps to provide high–quality weather and climate services that are tailored to the context–specific needs as well as mainstreamed into the policies and operations of the relevant sector line ministries and the community they serve. The NFCS is built on five pillars: observation and monitoring; research, modeling and prediction; climate service information system; user interface platform; and capacity building. In terms of building the manpower of the institute, the NMI Training and Education Directorate coordinates all human resource capacity building, including meteorological technicians and graduate skill training.

On the other hand, concerning the water resource according to the information received from the Ministry of Water and Energy, Ethiopia's huge hydropower potential is distributed in eight major river basins and their innumerable tributaries. The theoretical hydropower potential of rivers throughout Ethiopia is 366,451GWh with the technical exploitable potential of 48,030 MW (MoWIE, 2020). Yet, less than 8.5% of the potential has been exploited so far. The development of hydropower resources is given highest priority in the Ethiopian energy sector policy and strategies.

Hydrological monitoring in Ethiopia is carried out by the Hydrology Department of the Ministry of Water and Energy. Currently, there are about 509 (increased by 171 since the second national communication) operational stream gauging stations distributed over the major river basins. It is important to note at this point that still the existing climatological and hydrological observation network in the country is not adequate and evenly distributed. The management of the climatological, hydrological and other databases relevant to climate change also needs strengthening and financially supported. On the other hand, decisions made to respond against the impacts of climate change require substantial scientific evidence obtained through research focused on the causes, manifestations, and effects of climate change. The data and information on weather and climate provides useful inputs for proper planning in sectors such as agriculture, livestock development and food security, road, air and maritime transport, health and public safety, building and construction industry, disaster management, as well as water resources management.

With this regard, the NMI of Ethiopia is in–charge of carrying out research studies in the field of meteorology and implements this task through its Meteorological Research and Studies Directorate. The directorate is responsible for undertaking various types of meteorological researches and studies including climate modeling, air quality and climate change protection, and meteorological forecast validation and verification. Currently, the directorate has seven experts actively engaged on climate related research works and to encourage research works, the directorate conducts periodic "Call for Papers" for publication and appraises the submitted papers involving senior volunteer professionals from the Meteorological Society of Ethiopia.

For the first time in its history, the NMI published its research book of "Joint Scientific Journal of National Meteorological Agency and Ethiopian Meteorological Society (EtMS)" that is intended to support operational activities of the institute and deliver effective meteorological services for the wider range of multi–sector institutions, disaster risk managers, research communities and general public in Ethiopia (NMA, EtMS 2020). The various researches included in the research book are focused to improve data service provision and forecast, early warning and applied meteorological services as well as providing timely and accurate weather information and climate services to the users. In the first edition of Joint Scientific Journal of National Meteorological Agency and Ethiopian Meteorological Society entertained topics such as:

- Assessing the Impact of Climate Change on Wheat Production over Bale Zone of Ethiopia;
- Analysis of Climate Trend, Variability & Community Perception over Eastern Tigray, Ethiopia;
- The Effects of Climate Variability on Malaria Outbreak Over Abol Woreda in Benishangul Regional State of Ethiopia;
- Characterization of Rainy Season & ENSO Effect on Rainy Season in Amhara Region, Ethiopia;
- Trend Analysis of Temperature and Precipitation on Selected Belg Rainfall Benefiting Areas of Ethiopia; and
- Inter–comparison between Observation between Parallel Conventional and Automated Weather Observatory in NMA of Ethiopia were included in the publication.

Apart from this, other higher education institutions also carry out research related to climate change. So far, significant progress has been made in understanding the weather and climate of the country. Although meteorology and climatology research has been incorporated in graduate and undergraduate courses/programs, climate change curricula in higher institutes of education need to be enhanced. In order to overcome the challenges of data gap related to uneven distribution of meteorological stations, gridded data (4 km x 4 km) is developed by hybridizing satellite data and data from the existing stations that is updated periodically. Moreover, in order to assist research personnel on climate analysis and application (NMA map room) has been developed in collaboration with International Research Institute (IRI) of Columbia University.

5.8. Education, Training and Public Awareness

Climate change refers to a change in the state of the climate identified by changes in the mean of its properties, and that persists for an extended period. It is a complex issue with profound socio–economic consequences to the diverse sectors of the society and economy. Thus, education plays a major role in addressing climate–change related challenges. An increase in climate literacy amongst the young people fosters a change of attitude and behavior whilst mitigating and adapting to the impacts and consequences of climate change.

With this regard, Ethiopia is taking concrete steps to integrate climate change learning into school curricula. In 2016, a preliminary study on the status of Climate Change Learning in the Ethiopian Education Sector was conducted by the EFCCC with the support from the United Nations climate change (UNCC) learn (FDRE, 2019). It is for these reasons that the Government of Ethiopia has developed and adopted the National Climate Change Education Strategy (2017 – 2030). One of the priorities listed in the strategy is strengthening the integration of climate change education into the formal education system with special attention to primary and secondary levels of education. The content analysis review showed that the current curricula, almost at all levels, focus on environmental protection education with limited and patchy content and knowledge on climate change along with promoting the establishment of environment clubs at schools.

On the other hand, higher educational institutions such as the faculty of Meteorology and Hydrology of Arba Minch University has put substantial efforts into capacity building on climate change by embedding B.Sc. degree program in Meteorology and Hydrology and M.Sc. degree program in Climate Change and Development since 2009/10 academic year. The general objective of these programs is to provide a broad knowledge and understanding of the fundamental principles of Meteorology and Hydrology and the ability to apply that knowledge and understanding to solve national problems. The programs target to produce experts who can conduct investigations to better understand, prevent, or solve climate monitoring and modeling, water resources problems, etc. In addition to this effort, most universities have programs related to climate change. For example, the Center for Environmental Science, College of Natural and Computational Science, Addis Ababa University offers M.Sc. and Ph.D. programs in Atmosphere, Energy and Climate Change.

Apart from the formal education system that has been attempting to incorporate climate change into their system, annual reports submitted to the EFCCC from sector ministries revealed that a series of capacity building trainings and awareness sessions were offered to their staff and experts along with implementing the CGRE forum to evaluate, share experience, and offer recommendation for improvements. On the other hand, increasing knowledge and raising public awareness to integrate climate–friendly attitudes, resources and measures to reduce vulnerability and increase resilience are very critical to facilitating effective climate change mitigation and adaptation strategies. Hence, public awareness of the basic science, its uncertainties and the risks via all available modes of communication are vital in order to engage the public in a debate about the actions needed to combat climate change and reduce its future risks. With this regard, all sector ministries and other institutions are reaching the community via mainstream media and their social media outlets. The most important ones being EWCA programs that are broadcasted on the national radio and television. Moreover, the EFCCC also undertakes public awareness programs and supports local and international training of relevant stakeholders.

Furthermore, NGOs such as the World Vision Ethiopia are playing important roles in raising local awareness; encouraging community members to undertake practical climate change adaptation actions; assisting with the interpretation of early warning information for appropriate and timely action. Even with all these efforts, there is still more that needs to be done to enhance environmental and climate change education and awareness in Ethiopia.

5.9. Capacity–Building

Capacity building is a multi dimensional cross–cutting issue which transcends all of the activities relating to the implementation of the country's obligations within the Convention. Accordingly, in 2015 the Federal Democratic Government of Ethiopia developed the five–year "Climate Resilient Green Economy National Capacity Development Program". The program aims at identifying the available capacities and capacity gaps at system, institutional and individual levels for the implementation of CRGE initiative. Moreover, it intends to conduct detailed institutional, individual and system capacity assessment of finance and economic development at federal, regional and Woreda levels; identify gaps and opportunities for further capacity development; and develop sustainable capacity development programs as well as planning, budgeting and monitoring and evaluationtools.

The training program is estimated to cost about ETB 1.4 billion, and will build the capacities of government officials and experts at all levels of government, namely federal, regional, zonal, and Woreda (FDRE MoFEC, 2015). All in all, the training program targets more than 10,000 staff from Woreda and zonal administration and offices; about 1000 trainers from academic and research institutions; about 100 senior federal government officials; and tens of participants from media institutions. Moreover, effective REDD+ MRV system has been developed by involving academic, research, civil society organizations and line ministries (Bekele et al., 2018). The Food and Agriculture Organization of the United Nations (FAO), Joint research center (JRC), global support program (GSP) undertook short term training to build technical capacity of the EFCCC, academic institutions, other relevant line ministries and regional entities. Wondo Genet College of Forestry and Natural Resources, Hawassa University developed M.Sc. programs for MRV in agriculture, forestry and energy. With the technical support from FAO, Ethiopia equipped and staffed an MRV unit within EFCCC Forest Inventory and Resource Demarcation Directorate at the national level, with additional MRV units being established in four regional states (Bekele et al., 2018).

Other than these efforts, the major capacity building activities related to climate change include:

- Capacity building on CSA conducted for extension workers by ATA (ATA has a broad portfolio of CSA–related works). The contents of the training includes items such as conservation agriculture, enhancing agricultural decision making through enhanced access to climate information and supporting improved access to agrometeorological information.

- The development of "***maps-room***" application by NMI in collaboration with International Research Institute (IRI) of Columbia University that attempts to solve the uneven distribution of meteorological stations in the country;
- The capacity building made in establishing and equipping a laboratory for the investigation of the energy efficiency of material used for local household level energy stoves in Addis Ababa under the ministry of Water and Energy;
- Training of experts was undertaken at Ph.D., M.Sc., bachelors and diploma levels which has contributed to enhanced technical expertise, knowledge base and service delivery in the area of climate change;
- Increase in the number of functioning meteorological and climatological stations from 1,153 to 1,539 while operational stream gauging stations increased from 338 to 509 after the second national communication;
- Capacity–building program to comply with the Paris agreement and implement its transparency requirements at the national level;
- Training on climate change adaptation in the lowland ecosystems of Ethiopia; and
- Capacity building to scale up CSA and training of expert professionals on the area;

Besides these key capacity building activities, considering the challenges posed by the urban waste management to climate change, the Ministry of Urban and Infrastructure conducted a comprehensive national assessment on the solid waste generation, composition, collection and disposal coverage as well as the amount of wastes converted into resources through reuse and recycling. The findings of this study indicated that low solid waste collection, disposal coverage and converting wastes into resources due to financial constraints and low level of technical capacity; lack of public awareness, minimal political commitment in implementing integrated solid waste management systems. On the other hand, to tackle the problems identified by the assessment, the ministry developed a comprehensive INDC partnership plan exclusively focused on waste management for the climate change adaptation and mitigation in collaboration with development partners. According to sources from the Ministry of Urban and Infrastructure, the implementation of the plan indicates that at present there is one class II sanitary landfill and five class III controlled landfills while a number of them are on the pipeline.

5.10. Information and Networking

By its very nature the issues of climate change are of global nature that requires exchange and sharing of data, information, and expertise at national, regional and international levels in order to enhance appropriate and effective responses. Accordingly, Ethiopia participates in information sharing and networking at eastern Africa region level through IGAD climate forum, Africa Adapt knowledge sharing platform, and Global Climate Change Adaptation Network. The annual monitoring forum of the implementation of the CRGE plan conducted by the EFCCC has been one of the important in–house networks for exchanging information on climate change. Similarly, many of the Ethiopian policies related to climate change make provision for international collaboration and networking. At national level, strong institutional linkages and communication are established by building a network of stakeholders through electronic means of the government services portal. This will facilitate exchange of information and experience among experts. Moreover, an MRV web portal and web platform, a framework for a safeguards information system has been found to be an important networking system. Apart from these, there are civic organizations such as Ethiopian Biodiversity and Climate Change Forum and Forum for Environment that are established to serve as networks on climate change and environmental management.

Apart from these, the government of Ethiopia organized and participated in the “South–South Knowledge Sharing on Agricultural Mechanization " conference held in October 2017. The conference brought national and international researchers, policy makers, donors and implementers together to exchange experiences and promote cross– country learning on agricultural mechanization. The conference addressed experiences on agricultural mechanization in twelve countries in Asia and Africa (Bangladesh, India, China, Ethiopia, Sri Lanka, Vietnam, Thailand, Kenya, Myanmar, Tanzania, Nigeria, and Ghana). At this point in time, it is essential to note that Ethiopia must be able to strengthen the coordination, networks and information flows between ministries, different levels of government, civil society, academia and the private sector to have a more efficient integration of climate change variables into poverty reduction and development strategies.

5.11. Gender mainstreaming

Gender refers to the socially constructed differences between men and women and the resultant power relationships. Roles and expectations vary across cultures and can be changed by other variables including geographic location, age and religion. Gender equality is integral to all development decisions: it concerns the composition of participants, procedures and culture of development organizations plus their programs; and, it is the responsibility of men & women. The changes required for gender equality are not only to address why women and (some) men lack resources but also why they may not even access and utilize resources targeted towards them. Effective gender equality requires major changes at institutional, policy, organizational and resource allocation levels.

In order to ensure gender–responsiveness in Ethiopia’s NAP process, a targeted gender analysis has established a strong basis for moving forward. The analysis explored three main issues: gender differences in adaptation needs, opportunities, and capacities; equitable participation and influence in adaptation decision–making processes; and equitable access to financial resources and other benefits resulting from adaptation investments. This analysis was used to generate recommendations to address gender issues in the context of NAP–ETH, with specific recommendations for each of the adaptation options and strategic priorities. Women and men play different roles in their households and communities. Consequently, they have different experiences with the impacts of climate change, and thus have differing needs, opportunities, and capacities in relation to adaptation. The process of assessing the implications for women and men of any planned action, including legislation, policies or programs, in all areas and at all levels constitute the phenomenon of gender mainstreaming.

The ultimate goal of gender mainstreaming is to achieve gender equality. It is a strategy for making women's as well as men's concerns and experiences to be an integral dimension of the design, implementation, monitoring and evaluation of the policies and programs in all political, economic and societal spheres so that women and men benefit equally and inequality is not perpetuated. While some progress has been made, rural women often suffer more from poverty, which reduces their adaptive capacity. This reality still remains in place compared to their male counterparts. Many women face additional barriers to securing their livelihoods and adapting to climate change. If adaptation processes are to be effective, gender differences must be understood and gender-based vulnerabilities confronted.

In line with this, adaptation options geared towards addressing agriculture must be mindful of the differentiated roles of men and women and ensure equitable opportunities and benefits for them. The overall goal of the CRGE Facility gender mainstreaming strategy is to enable vulnerable women and men, young girls and boys to improve their livelihood, to raise their incomes and strengthen their resilience to climate change by creating equitable and fair opportunities for men and women to support a paradigm shift to low–emission and climate–resilient development. The CRGE Facility Gender Mainstreaming Strategy is the first of its kind to develop a gender specific operation tool in the climate change interventions in Ethiopia. The Strategy delineates the CRGE Facility commitment to:

- Strengthen interventions that accelerate gender equality, social inclusion and women's empowerment;
- Strengthen the integration of gender equality into CRGE Facility core work streams; and
- Better align CRGE Facility with its development partners including the GCF focus on gender equality and women's empowerment.

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